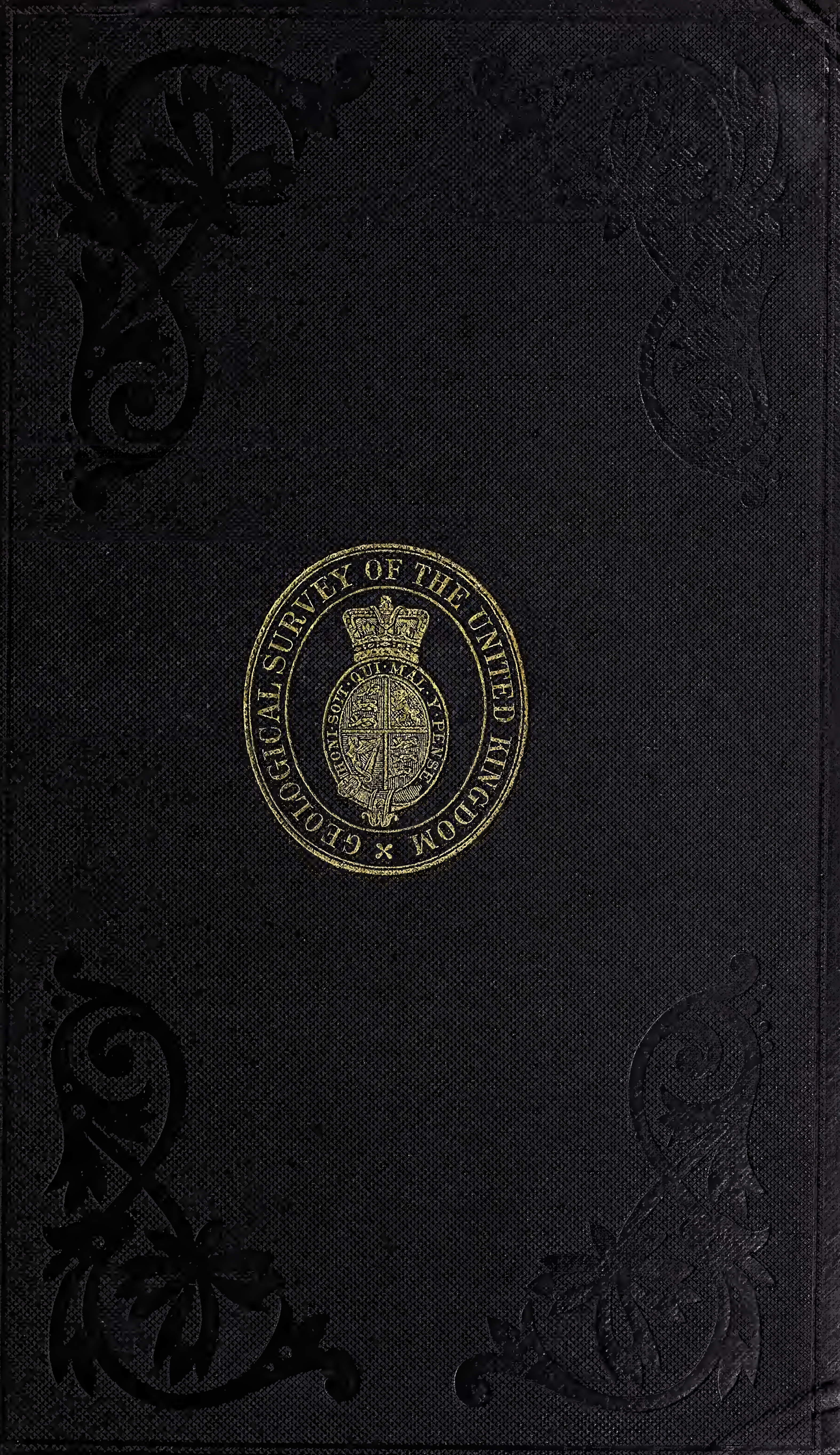

GEOLOGICAL SURVEY OF THE UNITED KINGDOM

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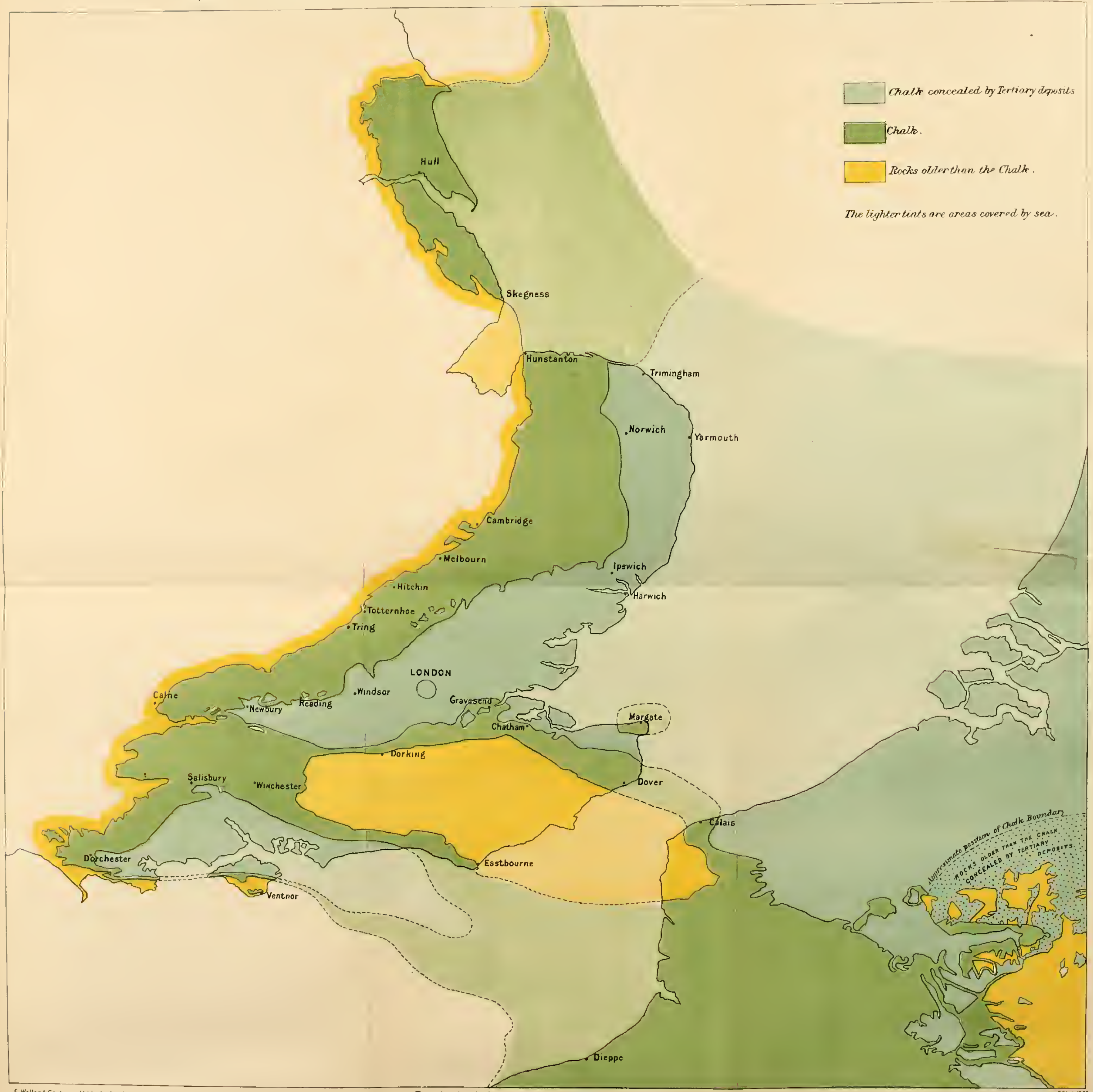
Plate 1.

MAP OF THE AREAS OCCUPIED BY THE CHALK IN ENGLAND & IN THE ADJACENT REGIONS.



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MEMOIRS OF THE GEOLOGICAL SURVEY
OF THE
UNITED KINGDOM.

THE
CRETACEOUS ROCKS
OF
BRITAIN.

VOL. II.—THE LOWER AND MIDDLE CHALK OF ENGLAND.

BY

A. J. JUKES-BROWNE, B.A., F.G.S.

WITH CONTRIBUTIONS BY

WILLIAM HILL, F.G.S.

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PREFACE.

In the Preface to the first volume of this memoir on the Cretaceous Rocks it was stated that the description of the Upper Cretaceous strata would be published in two volumes, but it has since been found more convenient to divide the work into three volumes. That now issued is the second of this series, and deals with the Lower and Middle Chalk; the third will include the description of the Upper Chalk, with chapters on Economics, the Water-supply, and the Physical Features of Chalk areas, together with a complete catalogue of the fossils found in all three divisions of the Chalk.

The delay in the publication of this volume is due partly to circumstances connected with the author's retirement from the Service, and partly to other causes, but the third volume is already in type, and will, it is hoped, be also published within the current year.

In the present volume the Lower and Middle Chalk are described as separate stages in the Upper Cretaceous Series; and the account of each includes not only the stratigraphical details of the beds, but also chapters on their microscopic structure and mineral contents, their chemical composition, and on the physical conditions under which they were respectively accumulated. In arranging the stratigraphical particulars the chapters have been made to coincide as far as possible with county-divisions, each chapter dealing either with one county or with parts of two or three counties.

The first chapter contains a brief history of the subdivision of the English Chalk into stages and zones, and for remarks on the nature and value of zones the reader is referred to Chapter III. of the first volume. Among the earlier geologists who contributed to our knowledge of the formation, the most notable are Mantell, W. Phillips, S. Woodward, and C. B. Rose; among the later are W. Whitaker, Caleb Evans, F. G. H. Price, and more especially, Dr. Charles Barrois, whose "Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande" has long been a mine of information on the subject.

In the preparation of this volume the author has had the valuable co-operation of Mr. W. Hill, who has not only contributed largely to the chapters on both the Lower and Middle Chalk of Kent, Surrey, Hampshire, Sussex, Dorset, Norfolk and Yorkshire, but has carried on elaborate investigations into the mineralogical and microscopic structure of the beds which compose this portion of the Chalk formation, the results of his researches being embodied in Chapters XXII, XXIII and XLIII.

4219. 750.—Wt. 18296. 5/03. Wy. & S.

The fossils collected by the Geological Survey have been named in the Palæontological department by Mr. E. T. Newton, with the assistance of Mr. H. A. Allen and Dr. F. L. Kitchin. Mr. Newton has further devoted much time to the troublesome matter of synonymy, and the lists of fossils throughout the volume have been revised by him.

We are indebted to Prof. F. Chapman (now of Melbourne) for examining and naming the Foraminifera and Ostracoda which were isolated by Mr. Hill in the course of his work, and Mr. Jukes-Browne desires to acknowledge the assistance he has received from Mr. R. M. Brydone, Mr. Ch. Griffith (of Winchester), Dr. G. J. Hinde, Mr. J. B. Hue (of Ventnor), Mr. E. Meyrick (of Marlborough College), and Dr. A. W. Rowe, who have all imparted valuable information respecting exposed sections and fossils obtained therefrom.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, Jermyn Street, London,
16th January, 1903.

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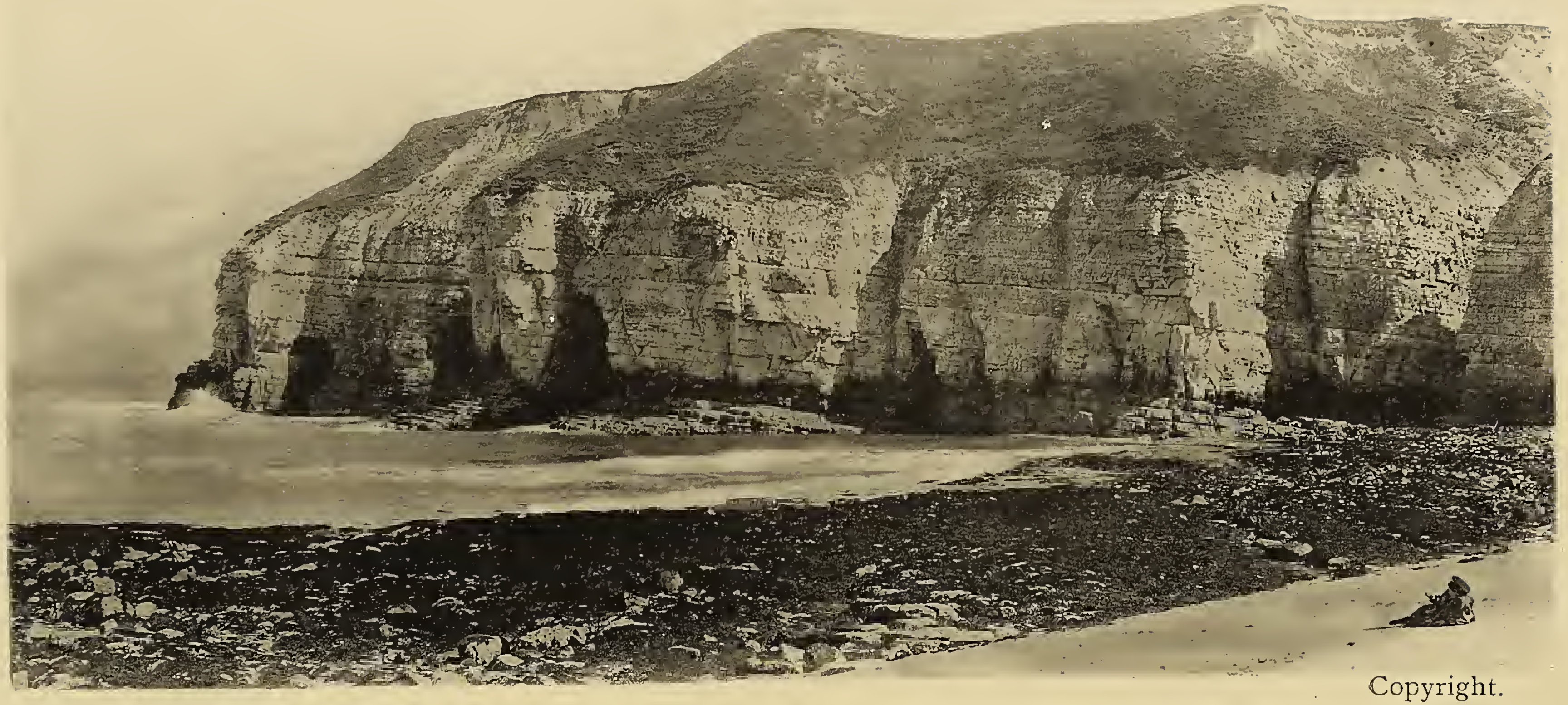

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Cliffs, eastern side of Great Thornwick Bay, Yorkshire.

From a Photograph by Mr. Godfrey Bingley.

THE CHALK OF ENGLAND.

CHAPTER I.

A GENERAL ACCOUNT OF THE CHALK AS A WHOLE AND A HISTORY OF ITS SUBDIVISION INTO PARTS.

The formation which geologists know as The Chalk consists for the most part of material which even those who are ignorant of Geology would call chalk, since this name (the softened form of the German *kalk*) has always been applied in England to the soft white or whitish limestone that is found over such large areas in the southern and eastern parts of the country. There are, however, within this great Chalk formation many varieties of chalk, some soft and some very hard; thus there are beds which are locally called *marl*, *malm*, and *clunch* (all argillaceous varieties), and others known as *rag*, *freestone*, and "*hurlock*" or "*harrock*" (all hard varieties). In Lincolnshire and Yorkshire, moreover, nearly all the chalk is hard, or rather hard, and in these counties it is still provincially called *kalk*.

The formation, considered as a whole, not only occupies a large surface area (see Plate 1), but underlies the whole of the London Basin and the whole area of Tertiary strata in Hampshire and Dorset. It must also extend eastward beneath the whole of the southern part of the North Sea, since it is known to underlie the Tertiary strata of south-eastern Belgium, and was traversed (with a thickness of 304 feet) in a deep boring at Ostende. Southward from Sussex and Hampshire it extends beneath the eastern part of the English Channel into France, where it occupies the shore-line from near Etaples to Cap la Hêve, near Havre.

How far Chalk underlies the bed of the North Sea east of the coast of Yorkshire we have at present no means of knowing, but as the Chalk of that county is clearly part of a deep basin, it is quite possible that the eastern lip of this basin may rise into an anticline from the ridge of which the Chalk has been, for a certain distance, completely removed.* But even if this is the case the Chalk doubtless comes in again on the eastern side of this anticline, and plunges below the deep Tertiary basin of Holland; its first appearance on the continental shore being on the island of Heligoland.

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* If a submarine boring could be made at the southern end of the Dogger Bank some very interesting geological information might thereby be attained, and such an undertaking does not seem beyond the capacity of modern engineering.

A few words may also be said respecting the original extension of the Chalk over areas from which it has since been removed by detritive agencies. That it was originally continuous over the elongate dome of the Wealden-Boulonnais area is a generally accepted fact, and that the formation also extended very far westward beyond its present boundary line will likewise be admitted by everyone, but we have no means of knowing how far it actually spread in that direction. There are gravels containing Chalk flints near Torrington in the north-west of Devonshire and also in South Wales (Glamorganshire) up to heights of 400 feet, and though these may not have been directly derived from the Chalk, it is highly probable that Chalk once covered large parts of those districts, and extended beyond the mouth of the Bristol Channel.

It can hardly be doubted that the Chalk was deposited over the whole of Central England, and extended across Cheshire and the Irish Sea to Antrim, where large tracts of it still exist beneath the protecting cover of the Lower Tertiary basaltic lavas.

That the Chalk, and especially its middle and upper portion, must have had a great westerly extension may be inferred from the great purity of the Chalk in the outliers which still remain in Devonshire, and from the great thickness of the formation as a whole. In the Isle of Wight its thickness is not less than 1,600 feet, in Norfolk it is probably about 1,300 feet, and in Yorkshire Mr. Lamplugh has estimated it at 1,270 feet, though the highest beds are not there exposed.

The continuity and comparative uniformity of the material composing this great Chalk formation have been a considerable hindrance to its scientific exploration. It is really divisible into at least three stages, each of which has special lithological characters and a special assemblage of fossils, but it is only within the last twenty years that these stages have been adequately recognised in England.

From this point of view the Chalk contrasts strongly with the Jurassic Series, which is obviously divisible into a number of consecutive rock-groups, each with a different set of fossils. Consequently when William Smith began to record the sequence of rocks in the neighbourhood of Bath he readily recognised the several local members of the Oolitic Series, as well as the overlying beds of " Blue marl " (Gault) and Greensand, but the Chalk appeared to him as a single formation, incapable of being definitely subdivided, except into a lower part without flints and an upper part with flints.

One of William Smith's contemporaries, however, whose residence in the Vale of Pewsey afforded him excellent opportunities of observation, divided the Chalk into three parts, and he was, in fact, the first to describe the bed which is now known as the Chalk Rock. This observer was the Rev. J. Townsend, whose book, published in 1813, is a mine of curious and generally accurate information hidden under a title which is not calculated to attract the geological reader.*

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* The Character of Moses established for Veracity as an Historian, by Rev. J. Townsend. 4to. London and Bath, 1813.

The following is his brief but accurate account of the Chalk in Wilts, which he describes as of three sorts:—

> 1. That of the most elevated parts of Hants and Wilts, which "is milk-white, fine in its grain, and smooth when cut, writes readily on wood, and is fit for the cooper, for whiting, for lime, and for manure. It is the *creta scriptoria* of Linnæus."
>
> 2. "In descending the hills from Everly to the Vale of Pewsey a second bed appears, hard, rubbly, and tinctured with green, unproper for the uses to which the former is applied, and fit only for the highways."
>
> 3. "Under this we find what is with us called a malmy chalk (*marga cretacea* Lin.), unctuous to the touch, of a grey or greenish white, unfit for any of the fore-mentioned purposes."

In the second of the above "sorts" it is evident that we have a description of the Chalk Rock which is now taken as the base of the Upper Chalk, and the third sort is in all probability the Lower Chalk which has its greatest thickness in Wiltshire, and is in parts tough and marly.

In the year 1818 two geologists were studying the Chalk of the south-east of England, and both published some account of its component parts. These were G. A. Mantell and William Phillips. Mantell's first publication was in that year, and was entitled "A Sketch of the Geological Structure of the South-eastern part of Sussex."* In this he describes the "Chalk formation" as comprising (*a*) Blue Marl, (*b*) Chalk Marl, (*c*) Lower or Hard Chalk, (*d*) Upper or Flinty Chalk. His Blue Marl, however, was really the Gault, so that his division of the Chalk was very little more than that of Smith's division into flintless and flint-bearing chalk.

About the same time W. Phillips had examined the fine exposure of the Chalk in the cliffs near Folkestone and Dover, but his memoir though read to the Geological Society in 1818, was not published till 1821.† His account is excellent so far as it goes, and the lithological characters of his several subdivisions are carefully described. The following is his grouping of the beds:—

1. Chalk with numerous flints, 350 feet, in two parts:
    - I. With few organic remains.
    - II. With many organic remains.
2. Chalk with few flints, 130 feet.
3. Chalk without flints, in two parts:
    - I. With many organic remains, hard and rough, 90 feet.
    - II. With few organic remains, soft and whitish, 50 feet.
4. The Grey Chalk, estimated at 200 feet.

The first division is what is generally known as Upper Chalk, its lower part being "the nodular chalk of Dover," which includes the equivalent of the Chalk Rock.

No. 2 and the upper part of No. 3 answer to what is now called the Middle Chalk, or, more accurately speaking, No. 2 is the zone of *Terebratulina*, and 3 I. includes the zone of *Rhynchonella*

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* In the Provincial Magazine for August, 1818.

† Trans. Geol. Soc., Vol. v. p. 1.

Cuvieri. His 3 II., or "Chalk without flints and with few organic remains," is the upper part of our Lower Chalk, and his Grey Chalk includes what was then usually called Chalk Marl.

From this it will be seen that Phillips made a very near approach to the modern mode of subdivision. He particularly notes the bed of soft marl (zone of *Actinocamax plenus*) which forms such a marked horizon between the two parts of his "Chalk without flints," and if he had only taken this clear physical line of demarcation, instead of making the presence or absence of flints his criterion, his divisions could have been accepted at the present time.

Phillips's description of the Dover Chalk was reproduced in Conybeare and Phillips's "Outlines of the Geology of England and Wales" (1822). In this book, however, the Chalk is separated from the Chalk Marl, and with the latter are included the Upper Greensand and Gault, the authors being under the erroneous impression that the Folkestone clay was an argillaceous portion of the Chalk Marl and that the Firestone beds or Upper Greensand were subsidiary beds in this formation (see Vol. I. of this Memoir, p. 21). Phillips's Grey Chalk is therein regarded as the upper or more calcareous portion of a Chalk Marl Group. (See "Outlines," pp. 104, 126.)

Mantell's "Fossils of the South Downs" was published in 1822, and he also classes the Gault and Chalk Marl together, calling the former "Blue Chalk Marl," and the latter "The Grey Chalk Marl." The Chalk, as distinct from the Chalk Marl, he only separates into Lower without flints and Upper with flints, but indicates no line of demarcation, so that many of his Upper Chalk fossils belong really to the Middle Chalk.

From 1822 to 1859 every English writer on the Chalk, with two exceptions, continued to use the vague and unsatisfactory divisions of :—

Upper Chalk with flints,
Lower Chalk without flints,
Chalk Marl and Grey Chalk,

without attempting to define the limits between them.

The two exceptions were Samuel Woodward, in 1833, and Daniel Sharpe, in 1853.

Woodward's division of the Norfolk Chalk* was not unlike that of W. Phillips, being into four parts, as below :—

Upper Chalk with many flints.
Medial Chalk with few flints.
Lower Chalk without flints.
Chalk Marl.

He roughly indicated the areas occupied by these divisions on his sketch map of Norfolk, but gave no exact indication of the limits between them. It is probable that his "lower or hard chalk" included beds which are now regarded as the base of the Middle Chalk, and that his Medial Chalk comprised beds both above and below the horizon of the Chalk Rock. Both S. Woodward and his friend C. B. Rose* drew special attention to the important fact that the several divisions of the Chalk contained different assemblages of fossils.

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* An Outline of the Geology of Norfolk, 4to and 8vo, Norwich, 1833, with a geological sketch map and plates of fossils.

As time went on this fact impressed itself on the collectors of Chalk fossils, so that in 1853 Mr. Sharpe recognised the necessity of recording the general stratigraphical positions of the fossils he described, but found himself obliged to be contented "with referring specimens to one or other of the following great divisions of the Chalk, which are easily recognised, although they are not separated by any well-defined lines."† His divisions are:—

1. Upper Chalk (Norfolk, Gravesend and Northfleet).
2. Middle Chalk, which contains but few fossils.
3. Lower or Grey Chalk, containing numerous fossils.

He places the Chloritic Marl at the base, and includes the Chalk Marl in the Lower Chalk. His Middle Chalk is completely undefined, as he refers to no sections, and the only fossils he refers to it are *Belemnitella quadrata*, *Ammonites peramplus*, *Am. bravaisianus* and *Am. Woolgari*—fossils which really occur at widely distant horizons.

The first real advance toward a definite subdivision of the Chalk was made by W. Whitaker in 1859,‡ who then described the Chalk Rock, and defined it as the topmost bed of the Lower Chalk, in Wiltshire, Berkshire, and Oxfordshire. He remarks that "where-ever the Chalk-rock has been seen in the above-mentioned country it forms an exact boundary between the Chalk with flints and the Chalk without flints." In 1865 the same observer determined the true position of the Totternhoe Stone, and distinguished the following subdivisions in the Chalk of Buckinghamshire:—

Chalk with flints		= Upper Chalk.
Chalk Rock		Lower Chalk.
Chalk with few flints		
Chalk without flints	hard and bedded § blocky and marly	
Totternhoe Stone		Chalk Marl.
Totternhoe Marl		

He found that these horizons could be followed for a long distance, and the outcrop of the Totternhoe Stone was engraved on one of the Geological Survey maps (46 S.W.), but no attempt was then made to estimate the range of the fossils in these subdivisions.

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* A Sketch of the Geology of West Norfolk, by C. B. Rose. Phil. Mag., Ser. 3, Vol. vii. pp. 171, 274, 370, and Vol. viii. p. 28 (1835–1836).

† Fossil Mollusca of the Chalk, Pal. Soc. Introduction.

‡ Catalogue of the Rock-specimens in the Museum of Practical Geology, Ed. 2, 1859, p. 296. See also Quart. Journ. Geol. Soc., Vol. xvii. p. 166.

§ This appears to have included the rocky chalk which is now known as the Melbourn Rock.

The first endeavour to establish a zonal classification of the beds by means of the fossils was made by Caleb Evans, whose paper on "Some Sections of Chalk between Croydon and Oxtead," was published in 1870.* In this district Mr. Evans distinguished six zones which he characterised by the following fossils and names :—

1. Zone with Micraster coranguinum=*Purley Beds.*
2. ,, ,, ,, ,, =*Upper Kenley Beds.*
3. ,, ,, Micraster corbovis and Holaster planus=*Lower Kenley Beds.*
4. ,, ,, Inoceramus Brongniarti and Galerites subrotundus =*Whiteleaf Beds.*
5. Zone of Ammonites peramplus and Inoceramus mytiloides=*Upper Marden Park Beds.*
6. Zone of Ammonites varians and Belemnitella plena=*Lower Marden Park Beds* (Chalk Marl and Grey Chalk).

At the end of his paper the following generalised classification is given :—

	Feet.
Upper Chalk (Purley and Kenley Beds)	250
Middle Chalk (Whiteleaf Beds)	75
Lower Chalk (Marden Park Beds)	? 190

In a subsequent paper† Mr. Evans distinguished between some of the species of *Micraster* and referred all the forms *found in his Purley and Kenley Beds* to *M. cortestudinarium*

In the same year (1870) Mr. G. Dowker subdivided the whole of the Kentish Chalk into six groups or stages, based on obvious lithological differences, giving them local names. The following is his classification‡ :—

1. Margate Chalk	Upper Chalk with flints.
2. Ramsgate Chalk	
3. St. Margarets Chalk	
4. Dover Chalk	
5. Chalk without flints	Lower Chalk.
6. Grey Chalk	

His "Grey Chalk" includes the Chalk Marl, and corresponds exactly with what is now known as Lower Chalk. His 4 and 5 include most of what is now classed as Middle Chalk. The St. Margarets chalk is the nodular chalk which is now recognised as including the passage beds from the Middle to the Upper Chalk, and has the representative of the Chalk Rock at its base. The Ramsgate Chalk comprises all the chalk which has frequent layers of flints, and the Margate Chalk is the comparatively flintless chalk above it. In this classification Mr. Dowker really seized upon the most prominent divisional planes in the Kentish Chalk, and if he had ever completed his collection and examination of the fossils he would probably have developed a complete zonal subdivision of the Kentish Chalk.

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* Proc. Geol. Assoc. Separate papers.

† Proc. Geol. Assoc. Vol. v. p. 150.

‡ Geol. Mag., Vol. vii. p. 466.

In 1876 Professor Ch. Barrois published a detailed account of the whole Upper Cretaceous series in England and Ireland, and showed that the same zones which he and others had established in France could be followed through England,* and could be grouped under the main divisions proposed by D'Orbigny. His classification may be summarised as follows:—

Divisions.	Zones.
Senonian	Zone of Belemnites.
	Zone of Marsupites.
	Zone of Micrasters.
Turonian	Zone of Holaster planus.
	Zone of Terebratulina gracilis.
	Zone of Inoceramus labiatus.
Cenomanian	Zone of Belemnites plenus.
	Zone of Holaster subglobosus.
	Chloritic Marl.
	Zone of Pecten asper.
	Zone of Ammonites inflatus.

In the zone of *Holaster planus* he placed the Chalk Rock, so that the line between the Senonian and Turonian was drawn at nearly the same horizon as that which Mr. Whitaker had recognised as dividing the Upper and Lower Chalk. The most important result of his work, to English geologists, was the definition of the lower limit of the Turonian, and the consequent establishment of a Middle Chalk. This, as we have seen, had been tentatively suggested by Mr. Caleb Evans, but Professor Barrois established it on a surer basis by showing that the real line of separation between the Turonian and Cenomanian fauna lay between his zones of *Inoceramus labiatus* and *Belemnites plenus*, that is considerably lower than the line taken by Caleb Evans.

It was, therefore, Professor Barrois who first demonstrated to English geologists that it was not only possible to divide the English Chalk into three parts or stages, but that the distribution of the fossils made this a natural and necessary mode of classification, It will be noticed, however, that his Cenomanian includes beds which lie below our Lower Chalk and form part of our Selbornian stage.

During the years 1875 to 1879 Mr. W. H. Penning and the writer were engaged on the survey of the neighbourhood of Cambridge, and the publication of Professor Barrois' Researches gave an impetus to our desire to establish some definite divisions in the Chalk of Cambridgeshire. We had found what appeared to be the representatives of the Chalk Rock and of the Totternhoe Stone, identifications which were confirmed by Mr. Whitaker himself; and I had noticed that the marly layer which Professor Barrois identified with his zone of *Belemnites plenus* was often associated with beds of very hard rocky chalk. A special examination of the line of country along the course of this horizon revealed the fact that these rocky beds were continuous and constant in character, and as they were well exposed in quarries near Melbourn, between Cambridge and Royston, they were named Melbourn Rock after that village.

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* Recherches sur le terrain Crétacé Supérieur de l'Angleterre et de l'Irlande. Mem. Soc. Geol. du. Nord, 1876.

As the horizons of the ChalkRock, Melbourn Rock, and Totternhoe Stone were all capable of being traced across the country and indicated by lines on the map, it seemed to us at first that the Chalk might be divided into four parts or stages. When, however, fossils had been carefully collected by Mr. Allen from all the pits found during our survey it became evident that the Totternhoe Stone was only a lithological variety of the Lower Chalk, while the Melbourn Rock and the Chalk Rock separated well-marked palæontological divisions of the Chalk.

The results of our examinations of the Cambridge Chalk, therefore, entirely agreed with those arrived at by Dr. Barrois, both with regard to the general succession of zones and the grouping of these zones into three stages. In other words, we made it clear that this Chalk was naturally divided into Upper, Middle, and Lower portions, and we demonstrated the possibility of drawing the boundary lines of these divisions on a geological map.

During the survey of part of East Lincolnshire from 1879 to 1883 I found that the Chalk of that county fell naturally into two divisions, which corresponded generally with the Lower and Middle Chalk of Cambridgeshire, and were divided by a set of hard rocky beds, which appeared to include a representative of the Melbourn Rock.* This conclusion was confirmed by the subsequent investigation of Mr. W. Hill, who also found the same divisions extend through the Chalk of Yorkshire.†

Meantime (in 1886), Mr. W. Hill and the author traced the zonal divisions of the Cambridge Chalk northward through Suffolk and Norfolk to Hunstanton, and described the gradual lithological changes which take place along this line of country.‡

Since the year 1884 the author has been engaged in collecting materials for the present Memoir, and in drawing the boundary lines of the Lower, Middle, and Upper Chalk through the counties of Hertford, Bedford, Buckingham, Oxford, Berks, South Wilts, Dorset, and Devon; the result being to prove the continuity of the Melbourn Rock and the Chalk Rock throughout these counties, except in Devonshire, where they lose their special characters.

The same divisions have been mapped in North Wilts and Hampshire by Messrs. F. J. Bennett and C. E. Hawkins, through Sussex by Mr. Clement Reid, and in the Isle of Wight by Mr. A. Strahan. The equivalents of the Melbourn Rock and the Chalk Rock were recognised at Dover by Mr. W. Hill in 1886,* and more recently Mr. Hill has traced the Melbourn Rock through Kent and Surrey in the course of explorations specially made for the Geological Survey during the years 1896 and 1897.

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* See The Geology of part of East Lincolnshire, Mem. Geol. Survey, 1887, p. 28.

† Quart. Journ. Geol. Soc., Vol. xliv. p. 320, 1888.

‡ Quart. Journ. Geol. Soc., Vol. xliii. p. 544, 1887.

It should be mentioned, however, that while the Melbourn Rock maintains its characters and position throughout these south-eastern counties, there is no bed of solid limestone with green-coated nodules like the Chalk Rock of more western counties, its place being taken by a considerable thickness of nodular chalk, in which harder rocky beds occur at irregular intervals.

It has indeed become apparent to Mr. Hill and myself, during the course of our joint and separate explorations, that the bed originally described by Mr. Whitaker as the "Chalk Rock," is only one of several beds of chalky limestone which make their appearance in and above the zone of *Holaster planus*, and also that layers of green-coated nodules are not confined to this one horizon. In tracing the base of this zone it is therefore necessary to pay more attention to fossils than to lithological characters.

In conclusion, it has been shown by the testimony of many observers that the Chalk of England can be divided into three parts or stages, LOWER, MIDDLE, and UPPER, which correspond roughly with the French stages known as Cenomanian, Turonian, and Senonian. Each of these stages is capable of further subdivision into zones, as will be pointed out in the sequel.

The LOWER CHALK comprises the beds which were formerly known as *Chalk Marl* and *Grey Chalk*, as well as a certain thickness of the "white chalk without flints." Over the greater part of England, its basement bed is a sandy glauconitic marl, often containing phosphatic nodules; in certain areas this has been called the Chloritic Marl, in others the Cambridge Greensand; but over the area of the Red Chalk its lowest bed is a pure limestone without any admixture of sand. Its summit is generally defined by a band of grey marl, in which the Belemnite *Actinocamax plenus* is frequently to be found.

The total thickness of the Lower Chalk varies from 250 to about 60 feet. In Devon its place is taken by calcareous sandstone and quartziferous limestone, varying from 1 to 40 feet in thickness.

The MIDDLE CHALK consists partly of hard rocky or nodular chalk and partly of firm white chalk. Its basement-bed is the hard nodular chalk to which the name of Melbourn Rock has been given. Flints are generally absent from the lower part, are sparingly distributed in its middle portion, but are sometimes numerous in the higher beds.

As defined in this Memoir the Middle Chalk does not include the Chalk Rock of the Midland and Eastern counties, but does include the bed to which that name has been applied in Dorset and in the

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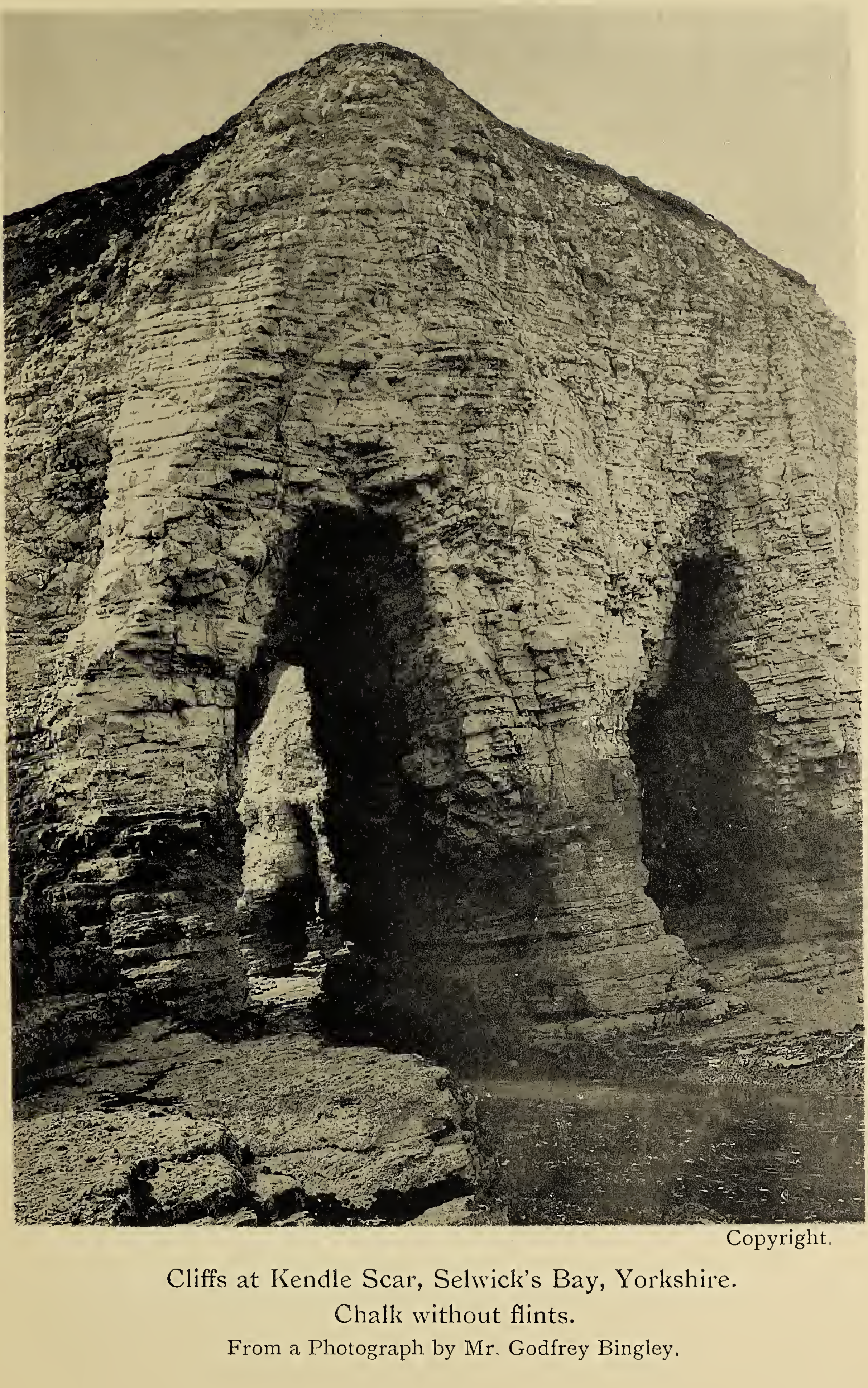
* On the Beds between the Upper and Lower Chalk of Dover, Quart. Journ. Geol. Soc., Vol. xlii. p. 232.

Isle of Wight. Where fully developed, as in the south-eastern counties, the Middle Chalk is about 240 feet in thickness, but in some districts it is less than 100 feet.

The Upper Chalk is less variable in lithological character than the Middle or Lower divisions; it consists in the lowest part of hard nodular chalk, in which beds of compact limestone frequently occur, one of which is known as the Chalk Rock; the greater part of this division, however, consists of soft white chalk, in which flints are generally abundant, but there is a certain zone or portion of it where flints are less common and which is sometimes almost flintless.

Where fully developed the Upper Chalk is more than 1,000 feet thick, but its actual thickness varies greatly in different parts of the country, owing to the great erosion which it suffered in the interval between the Cretaceous and the Eocene periods. Thus in the central parts of the London Basin, its thickness has been reduced to between 200 and 300 feet, and though it may never have been 1,000 feet thick in that area, it is probable that several hundred feet of chalk were removed before the formation of the lowest Eocene beds.



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Cliffs at Kendle Scar, Selwick's Bay, Yorkshire.
Chalk without flints.
From a Photograph by Mr. Godfrey Bingley.

CHAPTER II.

GENERAL ACCOUNT OF THE LOWER CHALK.

Definition and Limitation.

It is only within the last twenty years that what is now termed the Lower Chalk has taken rank as a definite stage in the Upper Cretaceous Series. In the earlier part of last century the name was used in a more or less indefinite manner for the lower part of the white chalk, excluding the Chalk Marl. After the discovery of the "Chalk Rock" by Mr. Whitaker in 1859, the term was used in Survey Memoirs, and in text-books published between the years 1860 and 1870, for the chalk which lay between that rock and the Chalk Marl.

In 1870 Mr. Caleb Evans made a more rational use of the term by proposing to include in it the Chalk Marl, but he still included some beds which are now referred to the Middle Chalk (see p. 6).

In 1876 Dr. Charles Barrois described the Chalk of England on the basis of the classification which had been worked out in France, and showed that the separation of the Turonian from the Cenomanian was very clearly marked throughout the south of England. English geologists, however, were not at that time prepared to accept the French scheme of nomenclature, and it was not till 1880, after the mapping of the country round Cambridge and the discovery of the Melbourn Rock, that the limits of the Lower Chalk were defined in a manner that could be adopted by the Geological Survey. This definition was published in the Geological Magazine (1880) and in the Survey Memoir on "The Neighbourhood of Cambridge" (1881).

In that memoir the zone of *Belemnitella plena* was included in the Melbourn Rock, because in Cambridgeshire and Hertfordshire it includes a medial band of hard rock; but a subsequent study of these beds* led to the separation of the Belemnite marls and their inclusion in the Lower Chalk. The plane of separation thus drawn was identical with that taken by Dr. Barrois as separating the Turonian and Cenomanian.

Beds included in Lower Chalk.

As now defined, therefore, the Lower Chalk includes all the beds of marl and chalk which lie between the highest bed of Gault or Greensand and the Melbourn Rock, which is the base of the Middle

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* On the Melbourn Rock and the Zone of Belemnitella plena, by W. Hill and A. J. Jukes-Browne. Quart. Journ. Geol. Soc., Vol. xlii. p. 216, 1886.

Chalk or Turonian stage. It includes, therefore, the beds which have been called *Chloritic Marl, Chalk Marl,* and *Grey Chalk,* together with a certain thickness of white or whitish chalk which has a band of grey marl at the top.

The question of the line of demarcation between the Upper Greensand (Selbornian) and Lower Chalk has given rise to much controversy, for the junction of the two formations presents very different aspects in different parts of the country. In some localities, especially where the highest part of the Selbornian consists of soft greensand, there is a gradual passage upward from this sand into the Chalk Marl, a part of the passage being generally occupied by sandy glauconitic marl containing small phosphatic nodules and casts of fossils. In other places, however, the plane of division is clearly marked, and a certain amount of current-erosion seems to have taken place, so that the base of the Chalk Marl rests on a waterworn surface, and contains a large number of phosphatic nodules and fossils, which in some places have clearly been derived from the erosion of pre-existent deposits.

In the southern counties any layer of glauconitic and noduliferous marl occurring at the junction of Greensand and Chalk has generally been called "*Chloritic Marl*;" but in the counties of Bedford, Herts, Cambridge, and Suffolk the junction bed is known as the "*Cambridge Greensand.*"

The name *Chloritic Marl* appears to have been a translation of the French *marne* or *craie chloritée,* and the first suggestion of it which we can find is a passage in a paper by Mr. Godwin-Austen (1843), in which he describes the base of the Chalk in Surrey as "becoming first a *craie chloritée,* till by further diminution of the calcareous matter we reach the bright green beds of the Upper Greensand with *Plicatula inflata.*"* Professor E. Forbes and Captain L. L. B. Ibbetson seem to have been the first to employ it as a designation for a particular chloritic (*i.e.,* glauconitic) marl, the mineral now known as *glauconite* being then confused with *chlorite.* Their "Chloritic Marl" was that at the junction of Greensand and Chalk in the Isle of Wight,† and Captain Ibbetson gave a more particular account of this stratum in a later paper,‡ the substance of which was incorporated in a little book published in 1849, entitled "Notes on the Geology and Chemical Composition of the Isle of Wight."

From that date this particular bed has always been known as "The Chloritic Marl," notwithstanding the misnomer involved in the term. Captain Ibbetson's description of the bed is, however, not free from ambiguity, and difficulties arose in ascertaining how much he meant to include in his Chloritic Marl, and which bed ought to be regarded as the base of the Chalk. Thus Mr. M. Norman, describing the Ventnor section in 1858,* distinguished what he termed *Chloritic Marl* from an overlying "Phosphatic Marl," and in a much later paper* (1882) he calls the latter the "Fossiliferous Marl," still applying the name *Chloritic Marl* to the underlying bed. Mr. Norman had, however, informed us in 1880 that both these beds were included by Captain Ibbetson under the name *Chloritic Marl,* and as he had often accompanied Captain Ibbetson, his testimony is of value.

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* Proc. Geol. Soc., Vol. iv. p. 169.

† Brit. Assoc. Rep. for 1844. Trans. Sec. p. 144.

‡ Brit. Assoc. Rep. for 1848. Trans. Sec. p. 69.

§ Geologist, Vol. i. p. 480.

There is, however, near Ventnor a third bed below the other two, and separated from what Mr. Norman calls the Chloritic Marl by a layer of rolled stones and phosphatic nodules. This is the bed referred to by Mr. C. J. A. Meyer in 1878, who regarded it as part of what had been called Chloritic Marl, and maintained that under this name there were included two beds, "which, although in actual contact, were in age widely separated," the one being the (local) top of the Upper Greensand and the other the (local) bottom of the Chalk Marl. This is quite true of the beds referred to by Mr. Meyer, but we do not think that the lowest bed was ever included by Captain Ibbetson in his Chloritic Marl.

Meantime the name Chloritic Marl had been applied to beds at the base of the Chalk in Dorset, Hants, and other counties. Mr. H. W. Bristow was surveying the western part of Dorset during the years 1846 and 1847, and the Geological Survey map (Sheet 18) was published in 1850. No descriptive memoir of it was issued, nor was any paper on the Chalk or Greensand of West Dorset published either by Mr. Bristow or by Professor Forbes, who examined the fossils collected from the district; but it is known that they regarded the basement bed of the Chalk in Dorset as the equivalent of the Chloritic Marl of the Isle of Wight. Thus Professor Forbes, under the description of *Galerites castanea,*† mentions the "Chloritic Marl" of Dorset, and the abundance of that fossil in it; and Mr. Bristow has recorded the opinion of Professor Forbes‡ that the "Chloritic Marl" of Dorset belonged to the Chalk and not to the Greensand, because *Scaphites æqualis* is a common fossil in it. This is true of the Dorset bed, but not of that in the Isle of Wight, and the facts as at present known make it probable that the nodule bed at the base of the Dorset Chalk is not the exact chronological equivalent of any part of the Chloritic Marl of the Isle of Wight, but is of slightly later date.

Again, Mr. Meyer had come to the conclusion in 1874 that certain beds at the base of the Chalk in Devonshire represented the Chloritic Marl of the Isle of Wight; and as many of the fossils occurred also in the highest bed of the Upper Greensand near Warminster (Rye Hill Sand), he thought that this also should be called Chloritic

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* Geol. Mag., Dec. ii. Vol. ix. p. 440.

† Decades of the Geological Survey, No. III., 1850.

‡ Geology of the Isle of Wight. Mem. Geol. Survey. Second edition (1889), p. 80. (Not in the first edition.)

Marl.* This view, with other points, was the subject of controversy at the time, but the differences of opinion were happily composed in 1894, when a joint note on the subject was written by Mr. Meyer and myself.† We pointed out that where the succession is most complete, as near Warminster and in the Isle of Wight, the soft Greensand which contains the special Warminster fauna is succeeded by a glauconitic marl containing phosphatic nodules and the peculiar siliceous sponge *Stauronema Carteri* (Sollas), but that in Dorset and Devon this *Stauronema* horizon does not occur. Hence, "if the name Chloritic Marl is to be retained—and it seems to die hard—we think it should be restricted to the horizon or 'hemera' of *Stauronema Carteri*, and that the name should cease to be applied to the *Scaphites* bed of Dorset and Somerset, or to any bed in Devonshire . . . . We think that the Warminster Greensand and its equivalents should be regarded as the summit of the Upper Greensand, and the *Stauronema* bed or Chloritic Marl as the lowest horizon which can be included in the Chalk, this horizon being sometimes absent through non-deposition."

Still more recently the junction beds near Warminster have been minutely studied by Mr. J. Scanes and myself, with the result that between the Chert Beds of the Selbornian and the Chloritic Marl with *Stauronema* we distinguish three separate layers and find that all the characteristic fossils of the Chloritic Marl, except *Stauronema*, range down through two of these layers. But whether these two layers should be included in the Chalk or in the Selbornian was left an open question.‡ We now think that they should be taken into the zone of *Am. varians* and regarded as the base of the Chalk.

Another deposit which has been called both Upper Greensand and Chloritic Marl is that which is more correctly known as the *Cambridge Greensand.* This is a dark sandy glauconitic marl, full of black phosphatic nodules and phosphatised fossils, which forms a constant bed at the base of the Chalk Marl along its outcrop in the counties of Bedford, Hertford, Cambridge, and Suffolk, resting directly upon an eroded surface of the Gault.

Up to 1875 the Cambridge Greensand was generally regarded as a thin local representative of the Upper Greensand, because it was supposed that the Gault was always succeeded by Upper Greensand. In 1872 Professor Bonney read a paper in which he correctly described the bed as occurring at the bottom of the Chalk, and as resting on an eroded surface of the Gault, and he regarded the nodules it contains as derived from the Gault: nevertheless he still considered the bed to be "the equivalent of the Upper Greensand of the south of England."* It was left for the present writer to show that it was really the basement bed of the Chalk Marl, and that as such it was newer than any part of the Upper Greensand. This conclusion was arrived at in 1874, after a study of the relations of the several formations, Gault, Greensand, and Chalk, in the counties of Buckingham and Bedford,† and he then found that Mr. Whitaker, who had mapped parts of those counties for the Geological Survey, had formed the same opinion.

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* On the Cretaceous Rocks of Beer Head. Quart. Journ. Geol. Soc., Vol. xxx. p. 381. See also Geol. Mag., Dec. ii. Vol. v. p. 547 (1878).

† Geol. Mag., Dec. iv. Vol. i. p. 494.

‡ Quart. Journ. Geol. Soc. Vol. lvii. p. 124.

One other deposit may be mentioned which up to the year 1877 had always been called "Upper Greensand." This is the green sand and marl which overlies the Gault at Folkestone, and is the bed in which *Stauronema Carteri* was first found. Mr. F. G. H. Price, writing in 1877,‡ pointed out that the fossils of this bed do not represent the fauna of the Upper Greensand of the west of England, and he rightly regarded it as the basal part of the Chalk Marl, calling it the zone of *Stauronema Carteri.* We agree with him, and consider it to be the stratigraphical equivalent of the Chloritic Marl of the Isle of Wight, as already defined and restricted.

The *Chalk Marl* has so long been used as a name for the lowest part of the Lower Chalk, wherever that is of a marly nature, that it would have been convenient to retain this name, if it were possible to define it so as to connote a definite subdivision of the formation even though it might not wholly consist of marly chalk.

Where the *Totternhoe Stone* exists this can be done, because the base of that stone can be taken as the upper limit of the Chalk Marl, but this is not very satisfactory, for the following reasons. In the counties of Norfolk, Lincoln, and York, the beds consist principally of rather hard greyish chalk, and contain little which is lithologically "chalk marl." Again, where the Totternhoe Stone is absent, as it is over the whole of the south of England, there is seldom any definite line which can be taken as the limit of the Chalk Marl, if this were regarded as a lithological subdivision, apart from any consideration of the distribution of fossils.

The *Totternhoe Stone* is another portion of the Lower Chalk which has well-marked lithological characters, but does not extend all over England. It takes its name from the village of Totternhoe, near Dunstable, where it has long been worked as a building-stone. It is a rough-feeling grey chalk, looking and feeling as if it was very sandy, but microscopical examination has shown that this roughness is not due to the presence of quartz-sand, but to the large proportion of small bits of broken shell which it contains. Its texture is compact and even grained, so that it works as a freestone, and it lies in thick beds, so that large blocks can be raised and cut into any shape. At its base there is generally a layer of green-coated calcareo-phosphatic nodules, and small fragments of brown phosphate are frequently scattered through the stone. Fossils are generally fairly abundant in it, especially *Rhynchonella mantelliana, Kingena lima, Pecten orbicularis, Pecten fissicosta,* and *Serpula umbonata.*

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* On the Upper Greensand or Chloritic Marl of Cambridge. Proc. Geol Assoc., Vol. iii. No. 1. p. 1 (1873).

† See Quart. Journ. Geol. Soc., Vol. xxxi. p. 256 (1875).

‡ Quart. Journ. Geol. Soc., Vol. xxxiii. p. 434.

The Totternhoe Stone does not exist in the southern counties, and has not yet been discovered in Wiltshire. It appears to set in as a thin bed in Berkshire, continues thence through Oxford and Bucks, swells out to its greatest thickness (15 or 20 feet) in the counties of Bedford, Hertford, and Cambridge, and thins again through Suffolk and Norfolk, till it is only 2 feet thick at Hunstanton. At that place it is a hard dark-grey, gritty-feeling stone, with the usual nodules at the base.* In this form it occurs throughout Lincolnshire and Yorkshire, where it was first identified by Mr. W. Hill in 1888,† its recognition there having been made feasible by the discovery of its existence at Hunstanton in 1886.

Grey Chalk is another name which has been used for a portion of the Lower Chalk. William Phillips (in 1818) seems to have been the first to have employed this as a name for a definite subdivision, and he applied it to all the greyer part of the Lower Chalk near Dover, down to its base, estimating the thickness of such "Grey Chalk" at 200 feet (see *ante*, p. 3). Phillips's account was reprinted in Conybeare and Phillips's Geology (1822), and on page 104 there is a note that "this bed of grey chalk might more properly be designated chalk marle," showing that they regarded them as synonymous terms.

Most subsequent writers preferred to use the name Chalk Marl for this and the equivalent beds elsewhere, and the latter name was eventually adopted in the Memoirs of the Geological Survey. It is important to remember, however, that up to 1877 no definite distinction existed between Chalk Marl and Grey Chalk, and that fossils recorded as obtained from the "Grey Chalk of Folkestone"‡ might equally well have been described as coming from the Chalk Marl. Mr. Whitaker testifies to the identity of the two things in his "Geology of the London Basin," p. 32 (1872).

Mr. F. G. H. Price, however, writing in 1877,§ proposed to restrict the name Chalk Marl to the very lowest part, and to use the term Grey Chalk for all the rest of the Lower Chalk; thus including though apparently he did not realise the fact, 50 feet of Phillips's "Chalk without flints." Following Mr. Price, we have in several different publications employed the name Grey Chalk in a similar way, applying it to all the beds which lie between the Totternhoe Stone and the marl with *Actinocamax plenus.*

This use of the name has not proved satisfactory, for the highest part of the Lower Chalk is always so nearly white that it cannot with accuracy be called grey, and this white or whitish chalk is sometimes 60 and even 80 feet thick.

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* See Quart. Journ. Geol. Soc., 1887, Vol. xliii. p. 561.

† See Quart. Journ. Geol. Soc., 1888, Vol. xliv. p. 325.

‡ e.g. In Dr. Wright's Monograph of the Echinoderms of the Cretaceous Formations, Palæontographical Society.

§ See Quart. Journ. Geol. Soc., Vol. xxxiii. p. 431.

2. Division of the Lower Chalk into Zones.

Since therefore none of the lithological names hitherto applied to portions of the Lower Chalk can be used without confusion or inconsistency, we are compelled to seek a more satisfactory method of subdivision in the guidance of fossils, that is to say, in the limitation of the range of certain species. A study of the distribution of the fossils of the Lower Chalk by various observers at different places has certainly established the fact that some species are either confined to or are much more common in the lower part; while others are common in the upper part, and in some areas are confined to that part. In this way we get a useful subdivision of the whole stage into two broad zones, or "*assises*," as the French would call them; the lowest zone is characterised by the presence of *Ammonites* [*Schloenbachia*] *varians* and *Rhynchonella grasiana*, the second one by *Holaster subglobosus*, *Holaster trecensis*, and *Actinocamax plenus*; *Ammonites* [*Haploceras*] *Austeni* also occurs.

The investigations made for this Memoir have proved that the guidance of these fossils is satisfactory over a large part of England, and further, that over these areas the limits of these two zones coincide with the more marked lithological differences in the character of the Chalk.

The range of *Ammonites* [*Schloenbachia*] *varians*, appears to be co-extensive over the whole of the English Cretaceous area, *i.e.*, the species appears to have died out or to have become very rare at about the same horizon over the whole region, and probably throughout the whole Anglo-Parisian basin, for so far as we can ascertain its range is the same over all the northern part of France.

With *Holaster subglobosus*, however, the case is different: its range is not everywhere the same. In the south-east of England, and thence westward to Wiltshire and northwards through the counties of Berkshire, Oxford, Bucks, Bedford, Herts, Cambridge, and Suffolk, it is very rarely found in association with *Am.* [*Schloenbachia*] *varians*; but is often abundant in the massive grey chalk which forms the central part of the Lower Chalk. Further north, however, it ranges downward to the base of the Chalk, and consequently ceases to be of any value as an index-fossil. In Dorset and Devon, again, it is also found at the very base of the formation in association with *Am.* [*Schloenbachia*] *varians* and other fossils of the lower zone.

In the Isle of Wight it occurs occasionally in the lower beds, but much more frequently in the higher zone, so that it can still be taken as an index-fossil.

So far as we know at present there is no species which is restricted to the upper part of the Lower Chalk, and is at the same time common enough in every district to be a useful index. It is more convenient, therefore, to retain *Holaster subglobosus* as the index of the normal or more prevalent aspect of the zone and to choose other species for indices in the other areas. In the counties of Lincolnshire and Yorkshire we may adopt *Offaster sphœricus,** which is not uncommon in the higher beds, is rare in the lower, and has not yet been found in any other part of England.

In Dorset fossils are very scarce in the higher beds, and *Holaster subglobosus* has not been found in them, but a few specimens of *Hol. trecensis* have been obtained, and in this county the zone may temporarily be indicated under the name of *H. trecensis.*

We are now in a position to give a general account of the two primary subdivisions or zones of the Lower Chalk.

1. **Zone of Ammonites varians.**—This zone varies considerably in lithological character; in some districts it consists largely of soft marly and more or less argillaceous chalk (the Chalk Marl of older writers), but generally these marly beds alternate with courses of hard, grey chalk, and in the more northern counties it consists entirely of more or less hard chalk with only thin seams of marl. In Berkshire and Wiltshire it contains beds of compact siliceous chalk, which sometimes contain nodules or concretions of impure flint; while in Dorset it appears to pass into a firm homogeneous and whitish chalk which encloses siliceous concretions with nuclei of true flint.

Where the zone of *Am. varians* is well developed and well exposed, as at Folkestone and in the Isle of Wight, certain subzones may be distinguished in it. In these localities the basement bed, commonly called the *Chloritic Marl,* but more accurately the "band" of *Stauronema Carteri,* is really a subzone of the more comprehensive zone of *Ammonites varians.* Above this some writers have recognised a band of *Plocoscyphia labrosa* (=*P. mœandrina*). Locally also certain species, such as *Scaphites œqualis* and *Terebratulina nodulosa,* are confined to, or specially abundant at, certain higher horizons, and might be used as indices of local bands or subzones; the geographical extension of such subdivisions being, of course, very much more limited than that of the inclusive zone.

Over a certain portion of the British area, *i.e.,* from Yorkshire southward as far as the Thames Valley and a little way into Berkshire, this zone is marked off from that above by a bed which has received a special name, the *Totternhoe Stone* (see p. 187). Where this stone does not exist there is a gradual passage from the one zone to the other, but wherever the fossils have been carefully collected from below upward, there is always an horizon beyond which

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* This Echinoderm was described under the name of *Holaster rotundus* in 1888 (see Quart. Journ. Geol. Soc., Vol. xliv. p. 364), but it proves to be identical with that described by Schlüter in 1869, and named *Offaster sphœricus,*

Am. [*Schloenbachia*] *varians* does not seem to occur, and in those districts where the lower beds consist mainly of marly chalk (or "Chalk Marl") the disappearance of *Am. varians* coincides with the horizon at which the Chalk Marl passes into more massive Grey Chalk.

The above description applies only to those districts where the zone of *Ammonites varians* really consists of chalk, or chalk-marl On the coast of Devon, however, we find a deposit which occupies the place of this zone, and contains most of its characteristic fossils, with many others which are peculiar to it, but this deposit is lithologically very different, being partly a calcareous grit or quartz-sand cemented by calcite and partly a quartzifers limestone. The palæontological relations of these remarkable beds were discussed in 1896,* when it was suggested that they might be known as the zone of *Ammonites Mantelli,* a species which is rather more common in them than *Am. varians.* We regard them as bearing the same relation to the Chalk Marl of eastern England as the typical *Cenomanian* of La Sarthe does to the *Rotomagian* and "craie glauconieuse," of northern and north-eastern France.

2. **Zone of Holaster subglobosus.**—The upper part of the Lower Chalk maintains a certain lithological type over a larger area than the lower zone of *Ammonites varians* does, although some differences make themselves apparent when it is traced into Lincolnshire on the one hand and into the Isle of Wight on the other.

Where the Totternhoe Stone is present, we regard it as the basement of this zone, but in the south of England, where the Totternhoe Stone is absent, the lower limit of this zone is somewhat indefinite; the marly chalk of the *Ammonites varians* zone passes gradually into firmer and more massive or blocky grey chalk, and where this change takes place *Am. varians* becomes rare, while *Holaster subglobosus* generally becomes common together with *Holaster trecensis, Discoidea cylindrica,* and spines of *Cidaris Bowerbanki.*

This grey chalk is succeeded by firm blocky chalk, which is nearly white, and in which fossils are so rare that in W. Phillips's excellent description of the Chalk of Dover, written in 1818, it is denominated as "chalk without flints and with few organic remains." The change from grey to white is always rapid, even when there is no marked plane of division between the two; but sometimes they are divided by a bed with special lithological characters, such as a layer of hard yellowish nodular lumps, or by a bed of hard grey chalk somewhat resembling Totternhoe Stone. Such a bed of grey chalk occurs near Tring and is locally known as "*rag.*"

This type of partly grey and partly white chalk extends over the whole of eastern England from Kent to Wiltshire and from Wilts to Norfolk, but with much variation in the relative thickness of the differently tinted portions, as well as in the total thickness of the zone. When it is traced to the south-west, however, and studied in the fine cliff sections of the Isle of Wight, we find that the whole of this zone of *Holaster subglobosus* consists of white or whitish chalk; moreover *H. subglobosus* and *H. trecensis* may be found readily up to the very top of it. We did not observe any change nor any means of separating the lower from the upper part.

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* See Quart. Journ. Geol. Soc., Vol. lii. p. 99.

This massive white chalk extends westward through Dorset, but at the same time becomes much less fossiliferous, though an occasional *Holaster trecensis* may be found, and here the zone is best indicated by this species, for *Holaster subglobosus* is much more abundant at the base of the Chalk in Dorset. In West Dorset, where the chalk of the *Am. varians* zone also becomes white and massive, it is quite impossible to draw any line between one zone and the other, though we believe both are represented.

In Lincolnshire and Yorkshire this part of the Lower Chalk has a rather different aspect. The lower part of it consists of rather hard, rough and lumpy, greyish-white chalk in regular beds, separated by thin layers or seams of grey marl, and in some places a portion of about 6 or 7 feet in thickness is coloured bright pink. The upper beds consist of smoother and more compact whitish chalk, and a similar portion near Louth is coloured pink or yellowish pink.

Holaster subglobosus is not uncommon in these beds both in Yorkshire and Lincolnshire, but is equally common in the zone of *Ammonites varians*, so that it will be more convenient to take *Offaster sphæricus* as the index of the upper zone in these counties; we may then speak of the zone of *Offaster sphæricus* as the equivalent of the zone of *Holaster subglobosus*.

At the top of the zone of *Holaster subglobosus* there are almost everywhere some beds of grey marl which frequently contain *Actinocamax plenus*, and have sometimes been called a zone, but, strictly speaking, they do not constitute a zone, and have no distinct zonal fauna. They may be regarded as a subzone, but it is seldom that many fossils occur in them, and we shall prefer to speak of them as the Belemnite Beds or Marls.

This band is generally a very narrow one, often only 3 or 4 feet thick, but in some places, as at Beachy Head and in South Dorset, it expands to 15 or 16 feet. Its lithological characters are remarkably constant, and palæontologically it is well characterised by the presence of *Actinocamax plenus*. It is traceable from Dover in the south-east to Cheddington in the west of Dorset, and from the Isle of Wight in the south to Speeton in Yorkshire in the north; the only exception to its continuity being the north-west of Norfolk, where it cannot be distinguished with certainty.

It consists either entirely or very largely of grey shaly marl, sometimes greenish-grey and sometimes yellowish or buff coloured; but over a large area this marl is divided into two layers or courses by a bed of hard white compact chalk, and in some few places it contains a kind of chalk conglomerate which consists of rounded lumps of hard white chalk embedded in a grey marly matrix.

The fauna of these beds is not a large one, and the fossils are a mixture of Lower and Middle Chalk species, making it evident that the deposits were formed during an epoch of transition from one set of conditions to another. One species (*Rhynchonella plicatilis*) has not yet been found below the Chalk Rock except at this horizon; the typical form of *Inoceramus mytiloides* makes its appearance here also, but *Holaster trecensis* is present, *Scaphites æqualis* has been found in Dorset, and *Actinocamax plenus* is a Lower Chalk species which here attains its largest size and most abundant development. This Belemnite is not to be found in every small exposure, but is fairly common in some localities, especially in the southern and midland counties.

The lower band of shaly marl sometimes rests on a slightly uneven surface of hard white chalk, and in some localities a certain amount of chalk seems to have been removed by erosion before the deposition of the marl. It might, therefore, seem more natural to regard this zone as the base of the Middle Chalk instead of the uppermost part of the Lower Chalk; but too much weight must not be given to small physical breaks of this kind, especially when they are found to be local, and are not accompanied by a great change in the fauna. There are large areas in which there is a complete passage from the firm white beds of the Lower Chalk, through grey marly chalk, into the Belemnite Marls. Further, in its minute structure, the white chalk of this zone resembles that of the Chalk below, and differs from that which overlies it.

The lithological characters, the fossil contents and the stratigraphical relations of this zone combine to prove that it was formed at a time of change when erosion was more prevalent than deposition; when, in fact, the bottom of the Cretaceous sea was swept by currents which were in some places strong enough to break up and wash away parts of previously existing beds.

Reviewing the English Lower Chalk as a whole, we may remark in the first place that it is a clearly defined formation, well marked off in most districts both from the underlying and overlying strata. In several areas its basement bed rests on an eroded surface of the Gault or Greensand, and even where there is a passage from Greensand to Chalk, the beds about the grouping of which any doubt can be felt are only 2 or 3 feet thick.

In respect of thickness, the Lower Chalk varies much; it attains its greatest development in Wiltshire, where it is not less than

250 feet thick; thence it thins northward, till in West Norfolk it is less than 60 feet thick, though it expands again to 130 feet on the Yorkshire coast. From Wiltshire eastward it maintains a thickness of over 200 feet through Hants and Surrey, and is not less than 190 feet in the east of Kent. Southward, at Culver, in the Isle of Wight, it is still over 200 feet, but it thins rapidly westward, and in some parts of Dorset it is not more than 80 feet thick, though probably on the average about 100 feet in the north-west of that county.

Where most clearly and fully developed, then, the Lower Chalk is made up of the several members shown in Fig. 1.

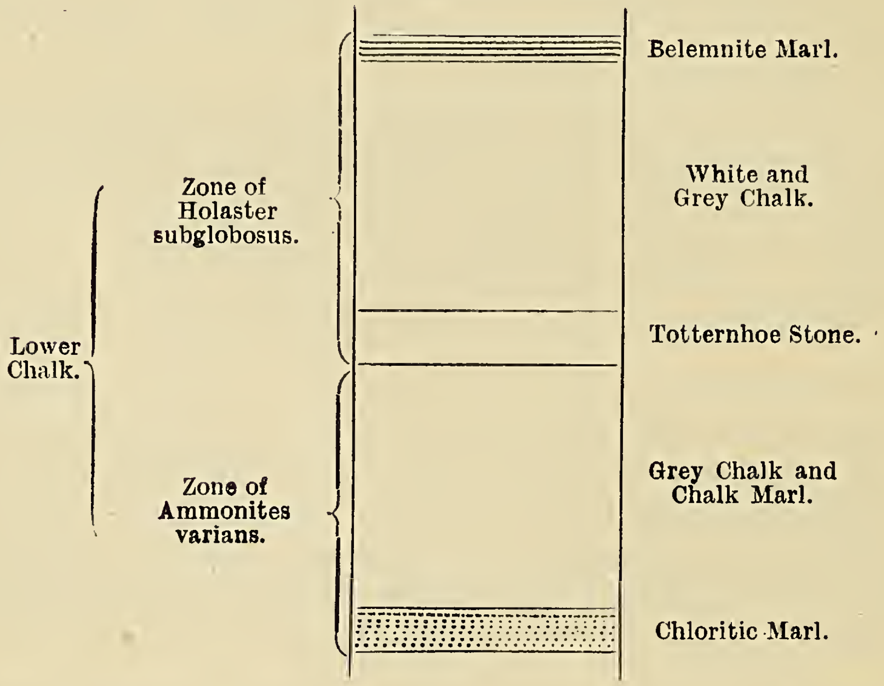

Belemnite Marl.
White and Grey Chalk.
Zone of Holaster subglobosus.
Lower Chalk.
Totternhoe Stone.
Zone of Ammonites varians.
Grey Chalk and Chalk Marl.
Chloritic Marl.

FIG 1.—Tabular view of the component parts of the Lower Chalk in districts north of the Thames.

Comparative views of the development of the Lower Chalk in different parts of the country are given on page 23, and at the end of the volume (page 558).

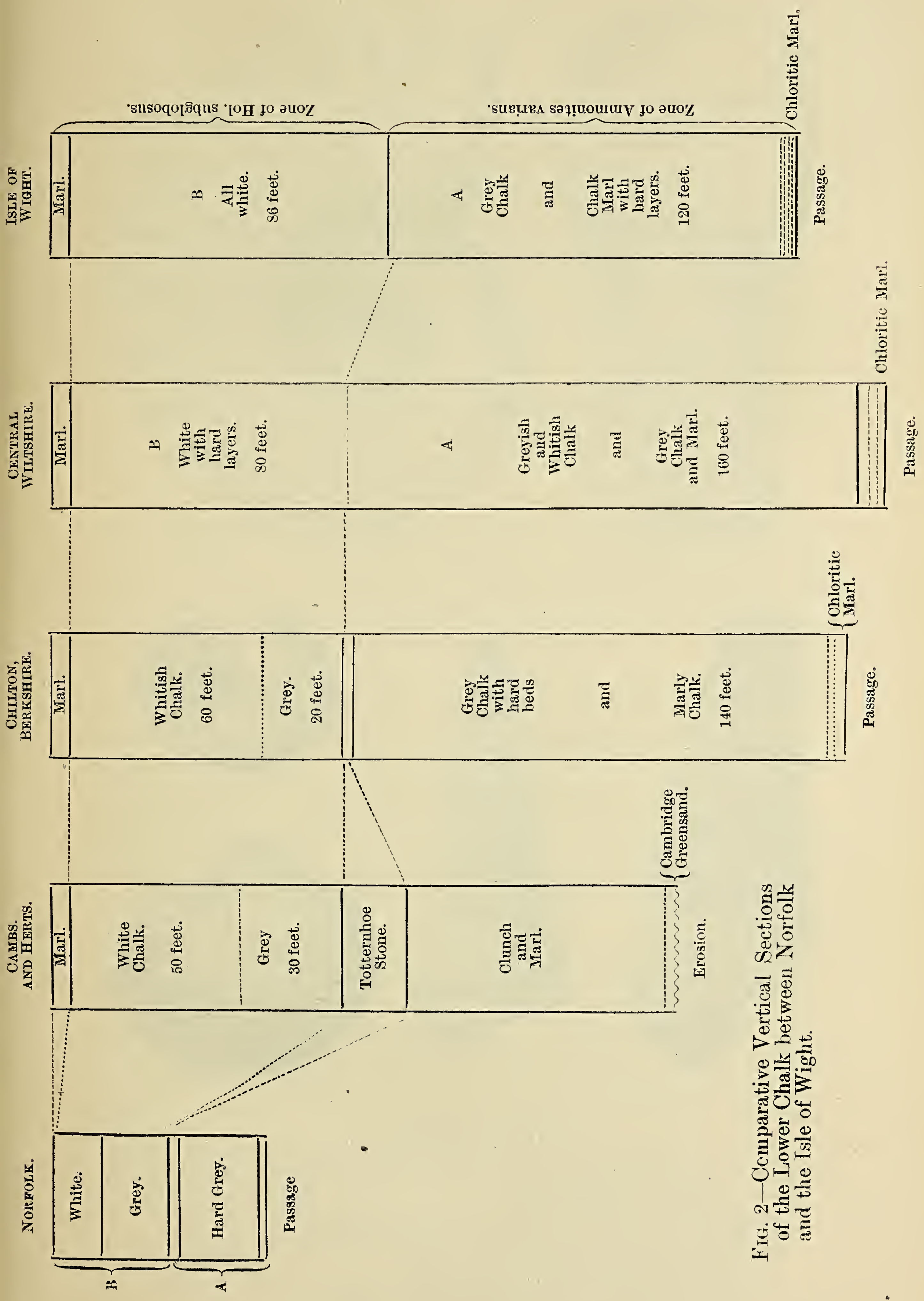
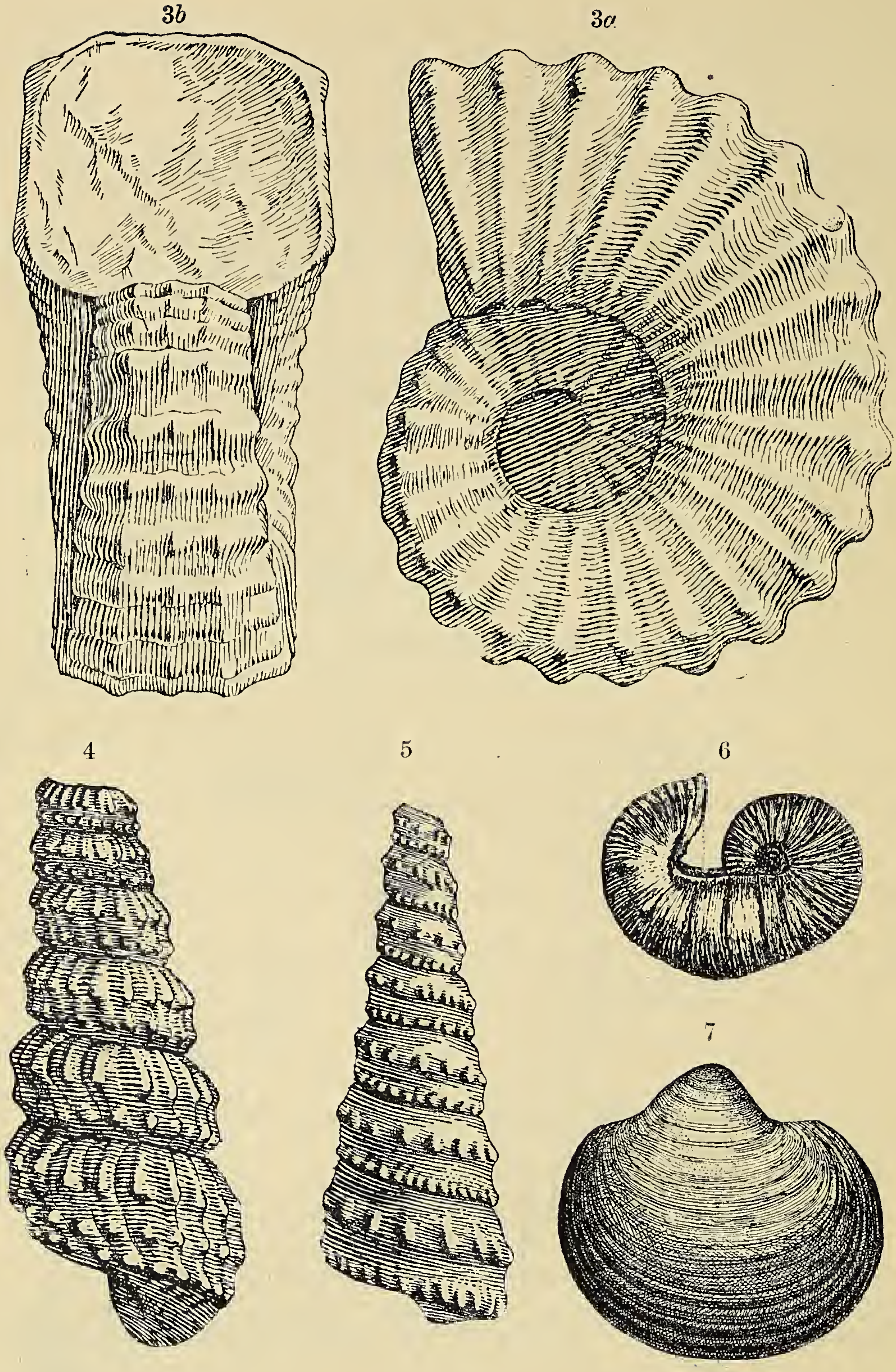


Fig. 2—Comparative Vertical Sections of the Lower Chalk between Norfolk and the Isle of Wight.



Lower Chalk Fossils.

Fig. 3—Am. [Acanthoceras] rotomagensis, *Brongn.* (half nat. size). 3*a*, side view ; 3*b*, front view.

„ 4—Turrilites costatus, *Lam.* (*two-thirds* nat. size).

„ 5—Turrilites Morrisi, *Sharpe* (nat. size).

„ 6—Scaphites æqualis, *Sow.* (nat. size).

„ 7—Unicardium ringmeriense, *Mant.* (nat. size)

3. Fossils of the Lower Chalk.

The fauna of the Lower Chalk, as a whole, comprises a very different assemblage of species from that which is found in the Gault of Folkestone or in that part of the Upper Greensand which represents the Upper Gault; in other words, it differs much from the fauna which is essentially *Selbornian*. A certain number of species, however, which make their first appearance at the top of the zone of *Pecten asper* become more abundant in the Lower Chalk, and some species like *Pecten orbicularis* and *Lima globosa* range up from the Gault itself; so that there are many links between the one fauna and the other.

The following is a brief résumé of the fauna of the Lower Chalk, with lists of the commoner and most characteristic fossils of this stage:—

Reptilia.—*Ichthyosaurus campylodon* and *Polyptychodon interruptus* range up from the Gault, and are not uncommon in the Lower Chalk. A remarkable Dinosaur, *Acanthopholis horridus*, also occurs, and the tooth of an *Iguanodon*, found by Mr. W. Hill near Hitchin, proves that this genus also continued to live on the land areas which bordered the Cretaceous seas.

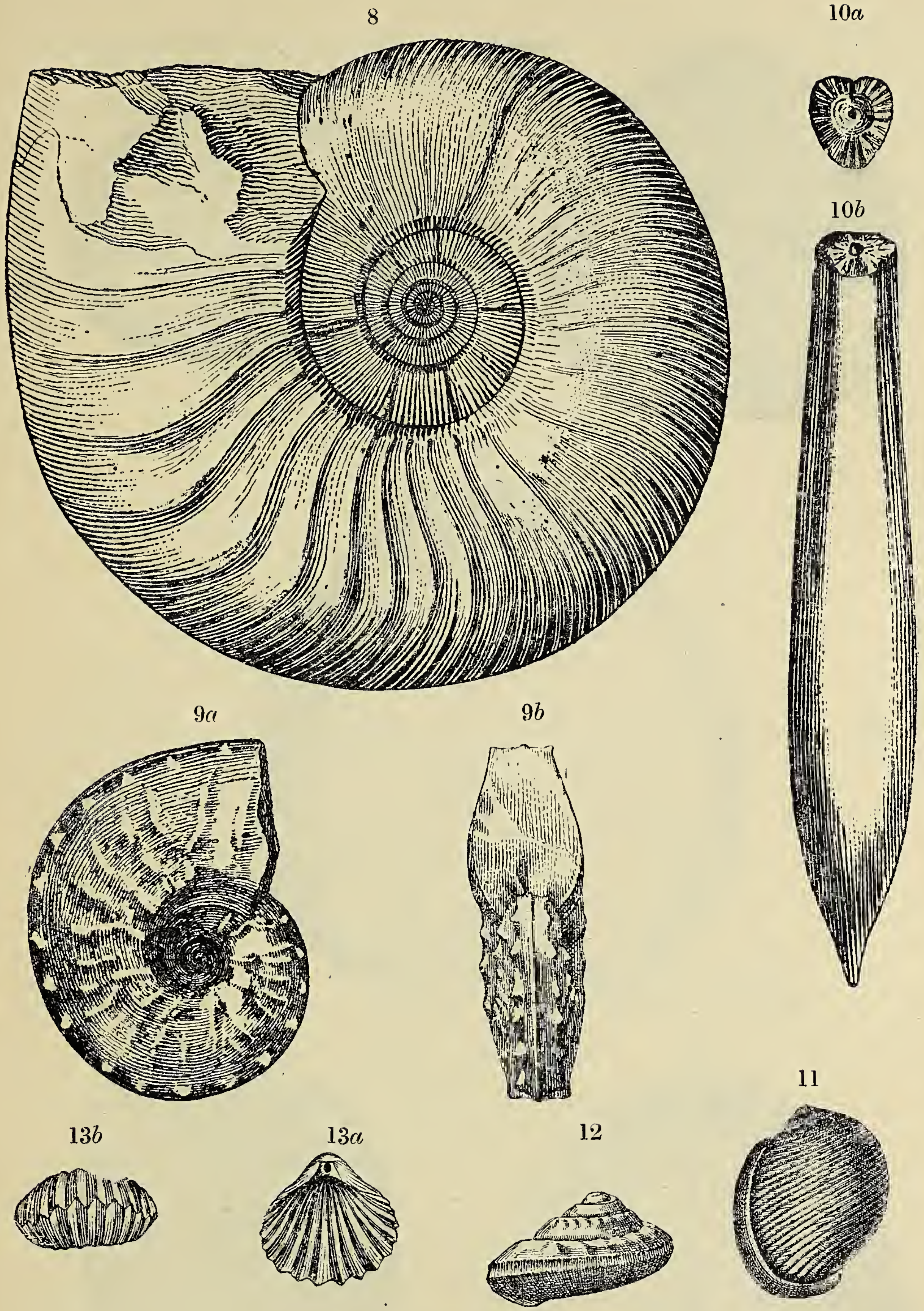
Pisces.—Remains of Fishes are common in Lower Chalk, but generally in the form of teeth. The crushing palatal teeth of *Ptychodus* often occur, the commonest species being *Pt. decurrens*. They are sometimes called "fossil slugs" by quarrymen. Teeth of various Sharks, such as *Lamna appendiculata*, *Oxyrhina Mantelli*, *Corax falcatus*, and *Notidanus microdon* frequently occur, but all these species range up into the Upper Chalk. Of Teleostean Fishes, *Beryx* (*Ctenothrissa*) *microcephalus* and *Hoplopteryx lewesiensis* may be mentioned.

Cephalopoda.—These became very abundant, and a large number of species belonging to many genera have been found in the Lower Chalk; they are, however, much more abundant in the lower than in the higher beds of the stage. The following list comprises the commoner and more important species, and shows their range, so far as it is at present known, the letter c indicating that the species is common, r that it is rare, and a + that it is moderately common.

	Zone of A. varians	Higher Beds.
Actinocamax lanceolatus, *Sow.*	+	+
,, plenus, *Blainv.* (Fig. 10)		c
Nautilus atlas, *Whiteaves*	+	
,, elegans, *Sow.*	c	
,, expansus, *Sow.*	+	
,, deslongchampsianus, *d'Orb.*	c	
,, sublævigatus, *d'Orb.*	+	+
Ammonites (Haploceras) Austeni, *Sharpe* (Fig. 8)	r	c
,, (Acanthoceras) cenomanensis, *d'Arch.*	+	+
,, (Hoplites) falcatus, *Mant.*	+	
,, (,,) ,, var. curvatus, *Sow.*	+	
,, (,,) lewesiensis, *Mant.*		+
,, (Acanthoceras) Mantelli, *Sow.*	c	r
,, (,,) navicularis, *Mant.*	c	r
,, (,,) rotomagensis, *d'Orb.* (Fig. 3)	c	c
,, (Schloenbachia) varians, *Sow.* (Fig. 9)	c	r
,, (,,) Coupei, *Brongn.*	c	r
Scaphites æqualis, *Sow.* (Fig. 6)	c	r
Hamites armatus, *Sow.* (Anisoceras)	+	
,, simplex, *d'Orb.*	+	
Baculites baculoides, *Mant.*	c	
Turrilites costatus, *Lam.* (Fig. 4)	c	
,, Morrisi, *Sharpe* (Fig. 5)	c	
,, scheuchzerianus, *Bosc.*	c	
,, tuberculatus, *Bosc.*	c	
,, Wiesti, *Sharpe*	+	

GASTEROPODA are not generally common, but some species occur in the Chloritic Marl and in the local basement beds of the Lower Chalk, and also at a certain horizon about 46 feet above the base near Folkestone. The commoner species are:—

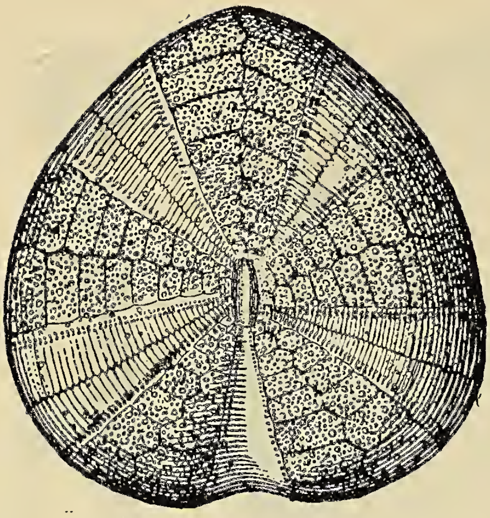
Aporrhais Mantelli, *Gardner*
,, oligochila, *Gardner*
Avellana cassis, *d'Orb.*
Cerithium ornatissimum *Desh.*
Dentalium majus, *Gardner*
Emarginula Gresslyi, *Pictet*
Pleurotomaria brongniartiana, *d'Orb.*
,, cassisiana, *d'Orb.*
,, perspectiva, *Mant.*
Solarium bicarinatum, *Tiessen* (Fig. 12)
Turbo rotomagensis, *d'Orb.*



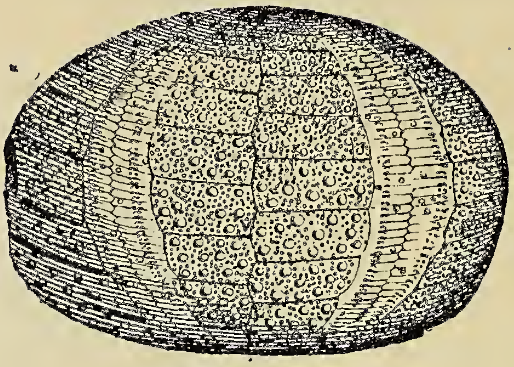
LOWER CHALK FOSSILS.

FIG. 8—Ammonites [Haploceras] Austeni, *Sharpe* (two-thirds nat. size).
„ 9—Ammonites [Schloenbachia] varians, *Sow.* (nat. size). 9*a*, side view; 9*b*, front view.
„ 10—Actinocamax plenus, *Blainv.* (nat. size). 10*a*, side view; 10*b*, apical view.
„ 11—Avellana cassis, *d'Orb.* (nat. size).
„ 12—Solarium bicarinatum, *Tiessen* (nat. size).
„ 13—Rhynchonella mantelliana, *Sow.* (nat. size). 13*a*, dorsal and 13*b*, front view.

14*a*



14*b*



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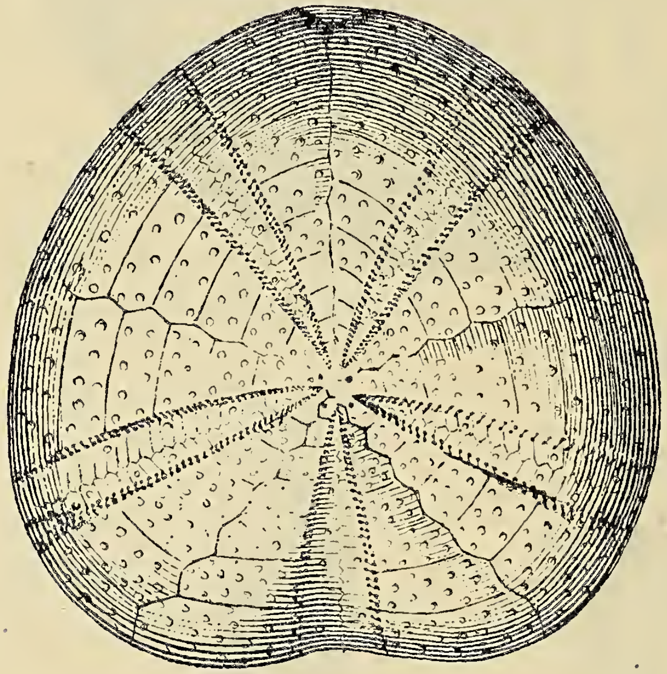

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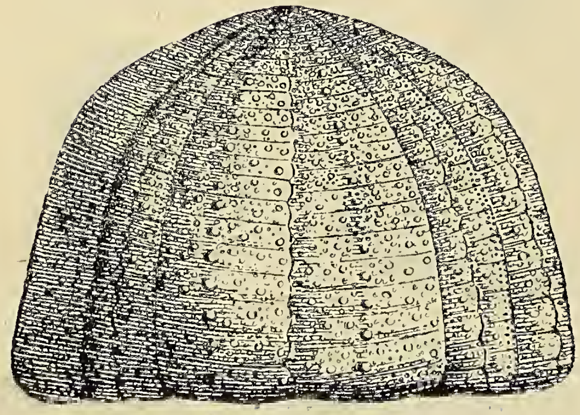

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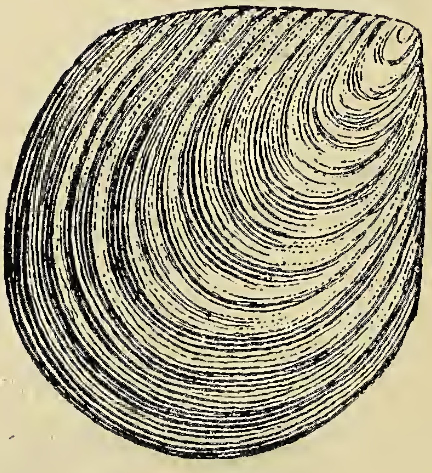


LOWER CHALK FOSSILS.

FIG 14—Holaster subglobosus, *Leske* (nat. size). 14*a*, apical view; 14*b*, side view.
,, 15—Discoidea cylindrica, *Lam.* (large specimen, nat. size).
,, 16—Holaster trecensis, *Leym.* (nat. size, apical view).
,, 17—Inoceramus latus, *d'Orb.* non *Mant.* (two-thirds of nat. size).

There are also species of *Scalaria, Fusus, Natica, Turbo, Trochus, Turritella*, and *Voluta* ; the occurrence of the *Voluta* being interesting as the earliest recorded appearance of the genus in England.

Lamellibranchiata are, as usual, common fossils. Several species, such as *Ostrea frons, O. vesicularis, Pecten orbicularis, P.* (*Neithea*) *quinquecostatus, Lima globosa* (Fig. 18), *Aucellina gryphœoides*, and *Plicatula pectinoides*, range up from the Selbornian. Species more distinctive of the Lower Chalk are the following :—

Cuculloea mailleana, *d'Orb.*
Exogyra haliotoidea, *Sow.*
Inoceramus latus, *d,Orb.* non *Mant.* (Fig. 17).
„ cuneiformis, *d'Orb.*
„ striatus, *Sow.*
Lima aspera, *Mant.* (Fig. 19.)
Pecten Beaveri, *Sow.* (ranges up).
„ elongatus, *Lam.* (= cretosus, *Goldf.*)
Radiolites Mortoni, *Mant.* (ranges up).
Pholadomya decussata, *Phil.*
Unicardium ringmeriense, *Mant.*

Brachiopoda.—These also form an important element in the fauna of the Lower Chalk, and the following are of common occurrence :—

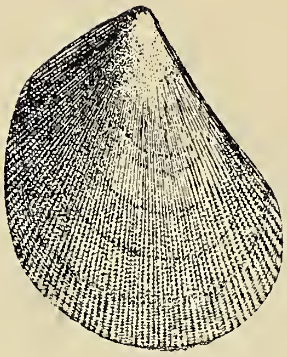
Kingena lima, *Defr.* (ranges from Gault).
Rhynchonella Martini, *Mant.*
„ mantelliana, *Sow.* (Fig. 13).
„ grasiana, *d'Orb.*
Terebratula semiglobosa, *Sow.* (ranges upward).
„ biplicata *Sow.* (ranges from Gault).
„ sulcifera, *Morris.*
„ squamosa, *Sow.*
Terebratulina triangularis, *Eth.*
„ nodulosa, *Eth.*
„ striata, *Wahl.* (ranges upward).

Bryozoa are not generally common in the Lower Chalk, though some adherent species may be found on the larger shells, but in the arenaceous limestones of Devon they are abundant, though few of them have yet been identified or named.

Crustacea.—Of Decapodous Crustacea the lobster-like *Enoploclytia* are the commonest (*E. brevimana* and *E. sussexensis*). *Palœga Carteri* has been found at several localities, but Crabs are rare. Cirripedes are not uncommon, *Pollicipes glaber* and *Scalpellum trilineatum* being those most usually met with.

Annelida.—Species of *Serpula* are common, *S. annulata* and *S. antiquata* often occurring, but *S. umbonata* (see Fig. 22) is the species most characteristic of the Lower Chalk.

19



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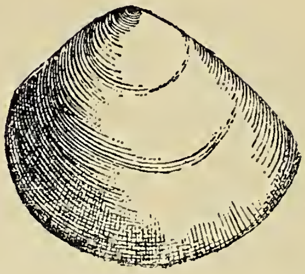

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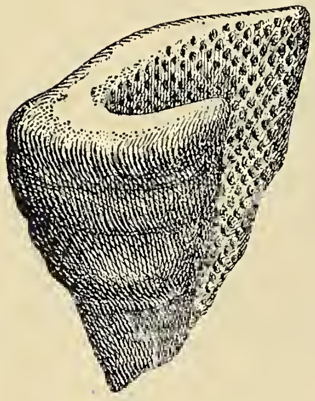

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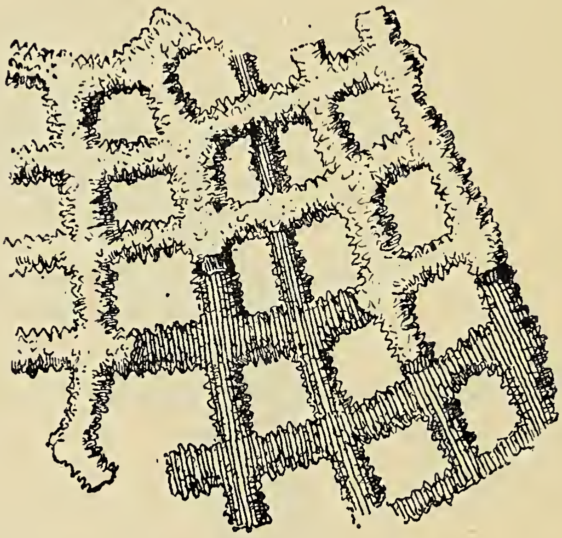
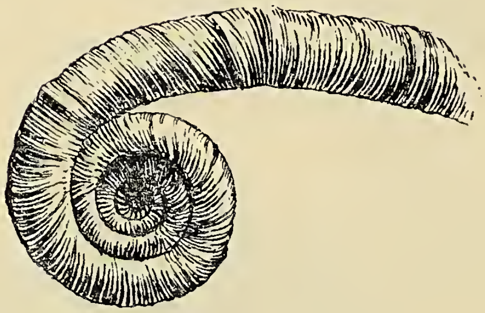
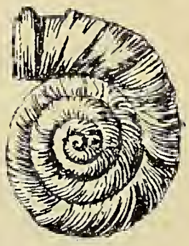


22*a*



22*b*



LOWER CHALK FOSSILS.

FIG. 18—Lima globosa, *Sow.* (nat. size).

" 19—Lima aspera, *Sow.* (nat. size).

" 20—Stauronema Carteri, *Sollas* (half nat. size).

" 21—Stauronema Carteri (mesh magnified).

" 22—Serpula umbonata, *Sow.* (nat. size). 22*a*, under surface; 22*b*, upper surface.

Echinodermata.—These are present in great variety and abundance, some of the species being specially characteristic of the Lower Chalk, though many of them make their first appearance as rare fossils in the very highest stratum of the Upper Greensand. The following is a list of the principal species:—

Cidaris Bowerbanki, *Forbes*
,, vesiculosa, *Brongn.*
Discoidea cylindrica, *Lam.* (Fig. 15)
,, subuculus, *Klein.*
Echinocyphus difficilis, *Cott.*
Galerites castanea, *Brongn.*
Hemiaster Morrisi, *Forbes.*
Holaster lævis, *Deluc.* (= carinatus, *Ag.*)
,, subglobosus, *Leske* (Fig. 14)
,, trecensis, *Leym.*
Offaster sphæricus, *Schlüt.*
Peltastes clathratus, *Ag.*
Pseudodiadema ornatum, *Goldf.*
,, variolare, *Brongn.*
Pentacrinus Agassizi, *Hag.*
Salenia Clarki, *Forbes*
,, Austeni, *Forbes*
,, petalifera, *Desm.*

Actinozoa.—The conditions prevalent in the sea of the Lower Chalk were unfavourable to the growth of Corals, and the only common form is a small flat cup-coral, *Micrabacia coronula*; another very small and elongate coral, *Onchotrochus serpentinus*, is also of occasional occurrence.

Spongida.—The remains of siliceous sponges are very abundant in some localities, *Craticularia Fittoni* and *Plocoscyphia labrosa* sometimes forming reef-like layers in the lower part of the Lower Chalk. The following are some of the commoner species:—

Craticularia Fittoni, *Mant.*
Heterostinia obliqua, *Benett*
Nelumbia tuberosa, *Hinde*
Phymatella intumescens, *Roem.*
Placotrema cretaceum, *Hinde*
Plocoscyphia labrosa, *Smith*
Siphonia ficus, *Goldf.*
Strephinia convoluta, *Hinde*
Stauronema Carteri, *Sollas* (see Figs. 20 and 21).

The last-mentioned is specially characteristic of the true Chloritic Marl, and does not range far above that bed.

CHAPTER III.

THE LOWER CHALK OF THE KENTISH COAST.

General Description.

We propose to commence our detailed stratigraphical account of the Lower Chalk with the section exposed in the cliffs between Folkestone and Dover, because this section is easily accessible; it has been already described by several writers, and the fossils have been collected from its several portions (zones and subzones.)

The earliest description is that by William Phillips in 1818 (Trans. Geol. Soc., Vol. v. Pt. 1, p. 16), who recognising the difference in colour between the upper and lower portions of what we now know as Lower Chalk, called the lower part "Grey Chalk," and classed the upper as part of his "Chalk without flints." To the upper he assigns a thickness of about 50 feet, and correctly describes it as having few organic remains, and states that it is separated from the hard massive chalk above by a band of soft marl. The thickness of the Grey Chalk he estimates at "not less than 200 feet," which is more than its real thickness, but he does not seem to have recognised the existence of the "Greensand" between it and the Gault, and consequently he does not fix its base. He remarks that where the Grey Chalk first rises from the beach, "its separation from the Chalk without flints is not at that place perfectly defined; in less than a quarter of a mile beyond this place the two strata are very distinct; the white being separated from the grey by some very thin beds of a sandy appearance and yellowish colour."

We have referred to Phillips's account more particularly because it remained the only description of the section for more than half a century, and was referred to by Mr. Whitaker in 1872 as "one of the best local descriptions (of the Chalk) that has been published." * Mr. Whitaker supplements this description by a few notes of his own, remarking that the soft bed at the top is about 6 feet thick, and contains Belemnites, and that the 50 feet of chalk beneath is "thickly bedded, breaking into large blocks." Of the Grey Chalk he says, "the top seemed to me fairly marked near Shakespeare's Cliff by the change of colour, the grey chalk having wavy dark lines along the bedding. Near the top there is a more massive bed, about 8 feet thick, which at Hay Cliff has small hard projections, some being pyrites, some fossils, and others stony lumps." He also comments on the "great

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* Geology of the London Basin, Mem. Geol. Survey, Vol. iv. p. 30.

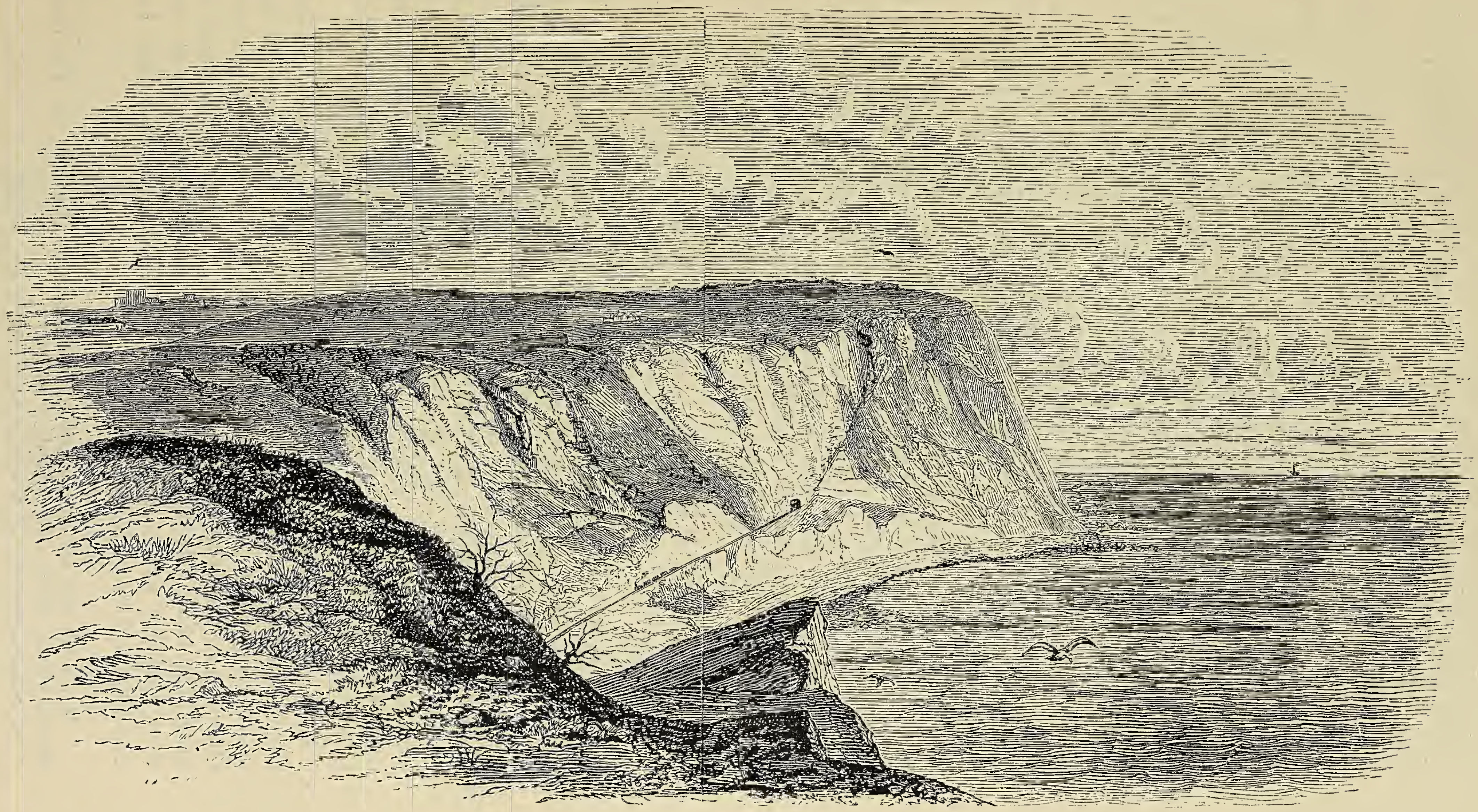
Dover Castle.
Abbot's Cliff.

FIG. 23—View of the Chalk Cliffs east of Folkestone, from Folkestone Warren.

thickness allowed for the Grey Chalk" by Phillips, and thinks that "more than the true 'Chalk Marl' may have been included under that name."

In 1875 Messrs. Potier and de Lapparent examined the chalk cliffs on each side of the Straits of Dover for the Channel Tunnel Company. In their report* they adopt Phillips's sub-divisions and estimates of thicknesses, but his "Grey Chalk" they divide into two "assises;" the upper assise they number VI. and describe as "argillaceous chalk of a dark bluish-grey colour, rather pyritous, compact; the upper part is rather hard but cuts smooth under the hammer (se polit sous le marteau); some yellowish beds." The lower assise (VII.) is described as "chalk of a rather lighter bluish-grey, argillaceous throughout, with some harder sandy beds."

They give 45 metres as the thickness of No. VI., and assign 15 metres to No. VII., but it is evident that these figures are merely estimated proportions of Phillips's 200 feet, and that they did not measure the beds themselves.

Professor Ch. Barrois briefly described the Folkestone section in 1876,† but with the exception of separating what he then considered to be "Chloritic Marl," he does not make any division of the Lower Chalk, classing all as the "assise à Holaster subglobosus." He refers, however, to the divisions of Messrs. Potier and de Lapparent and compares these with the palæontological zones which he had himeslf established in the Boulonnais, correlating them as follows:—

V. of Potier and de Lapparent = zone of Belemnites plenus.
VI. ,, ,, = zone of Am. rotomagensis.
VII. ,, ,, = zone of Am. varians.

In 1877 Mr. F. G. H. Price made a still more detailed study of the section and employed Griffiths, the local collector of fossils, to collect systematically from every portion of the Lower Chalk. Mr. Price remeasured the section, and found the total thickness from the base of the so-called "Greensand" to the top of the "Belemnite Marl" to be 197 feet. He divided the whole into seven "beds," which are essentially palæontological subdivisions based on the results of his fossil-collecting, but are not subzones of equal palæontological value.

In this paper Mr. Price proposes to make a distinction between Chalk Marl and Grey Chalk, but he only takes the lowest 10 feet of the Grey Chalk, and, grouping them with the underlying marly Greensand, calls the *ensemble* Chalk Marl. On the other hand, he takes the Grey Chalk up to the top of the Belemnite band, and thus includes much more than either Phillips or Whitaker had regarded as Grey Chalk.

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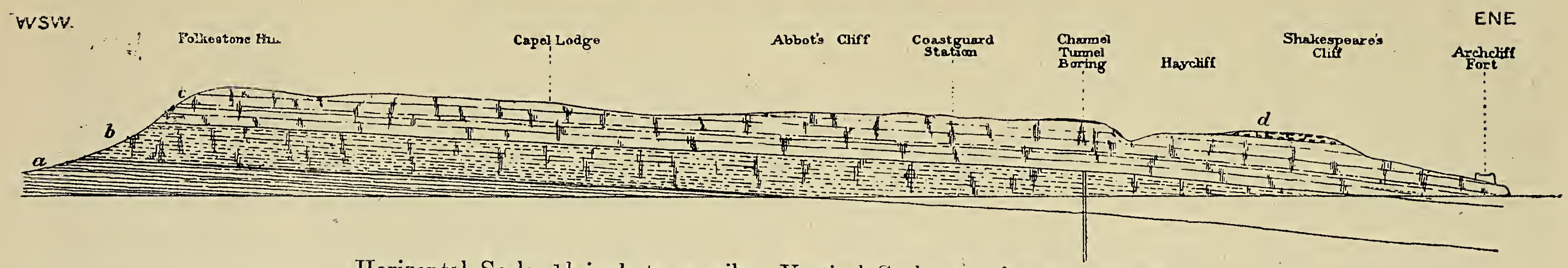
* Rapports sur les Explorations Géologiques (Chemin de Fer Sous-Marin), Paris, 1875. Republished in 1877.

† Recherches sur le Terrain Crétacé Supérieur, p. 130.

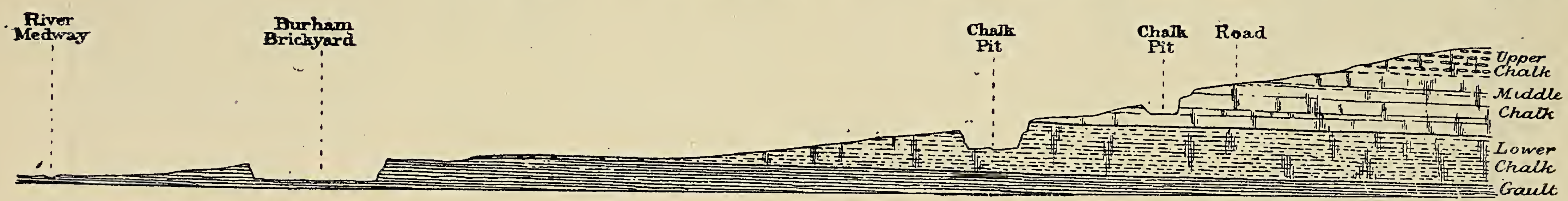
FIG. 24.—Section along the cliffs from Folkestone to Dover.



Horizontal Scale, $1\frac{1}{2}$ inch to a mile. Vertical Scale, 900 feet to an inch.

d. Base of Upper Chalk.
c Middle Chalk.
b. Lower Chalk.
a. Gault.

FIG. 25.—Section through the brickyard and the chalk pits near Burham.
Drawn from levels supplied by the Manager of the Burham Brick and Tile Company.



Horizontal scale, six inches to a mile. N.B.—The slope above the higher chalk-pit should have been drawn steeper and higher so as to include the basal part of the Upper Chalk.

Mr. Price appears to have imagined that the "marl with *Belemnites*" occurred at the top of what previous writers had called Grey Chalk, and to have identified it with the "thin yellowish beds" mentioned by Phillips; whereas in reality these bands are more than 50 feet below the *Belemnite* marl, which is at the top of Phillips' white chalk with few fossils (No. 6 of Mr. Whitaker). It was therefore a mistake to include this white or whitish chalk under the head of "Grey Chalk."

The point will perhaps be made clearer by throwing the different classifications into a tabular form, thus:—

<table>
<tr><th>PHILLIPS.</th><th>WHITAKER.</th><th colspan="2">POTIER AND DE LAPPARENT.</th><th colspan="2">PRICE.</th></tr>
<tr><td>Soft Marl.</td><td>Marl with Belemnites.</td><td colspan="2"></td><td>Bed VII.</td><td rowspan="4">Grey Chalk.</td></tr>
<tr><td>Chalk with few organic remains. Soft and whitish.
Yellowish beds.</td><td>Bed 6.
Blocky Chalk.</td><td colspan="2">No. V.</td><td rowspan="2">Bed VI.
Zone of Holaster subglobosus.</td></tr>
<tr><td rowspan="4">Grey Chalk (base not fixed).</td><td rowspan="3">Bed 7.
Grey Chalk or Chalk Marl.</td><td>No. VI.</td><td rowspan="3">Grey Chalk.</td></tr>
<tr><td rowspan="2">No. VII.</td><td>Beds III., IV., V.
Zone of Am. varians and Am. rotomagensis.</td></tr>
<tr><td>Bed II.</td><td rowspan="2">Chalk Marl.</td></tr>
<tr><td>Upper Greensand.</td><td colspan="2">No. VIII.</td><td>Bed I</td></tr>
</table>

Mr. Price informs us that he did not observe any horizon which he could take as a line of division in his Bed VI., and that, so far as his evidence went, the principal fossils ranged throughout its thickness. But as all previous observers had recognised a difference of colour and texture in the upper 50 feet, and as the French writers agree in making this a separate zone, uniting it with the marl above as the zone of *Belemnites plenus,* it was thought desirable to re-examine the section. This was done by Mr. W. Hill, and the result confirms the descriptions of Messrs. Phillips and Whitaker, for though fossils are few in the higher part of the Lower Chalk, yet the difference of colour is marked, and the change from grey to white agrees with the facts observed at many other inland localities, so that it is not a mere local accident of colour.*

Moreover, it was found that the chalk in the lower 19 feet of Mr. Price's Bed VI. was very marly, and contained *Ammonites varians* with other Chalk Marl fossils. We think, therefore, that this 19 feet should be grouped with the Chalk Marl and that Bed VI. is capable of separation into four beds, quite equal in importance to any of those below, though some are less fossiliferous.

The following, then, is our subdivision of the Lower Chalk between Folkestone and Dover, the beds being numbered from below upwards, and Mr. Price's numbers being given for comparison :—

			ft.	Mr. Price's Beds.
	9	Belemnite marl	6	VII.
White Bed.	8	Massive white chalk with *Holaster trecensis* and *Discoidea cylindrica*	53	VI.
Grey Chalk.	7	Greyish chalk in thin beds with stony lumps—large *Ammonites*	7	
	6	Grey chalk with few fossils	60	
Chalk Marl.	5	Grey marly chalk, fossiliferous	19	
	4	? The cast bed ; many fossils	? 2	V.
	3	Soft grey marl with two hard beds at the top, *Am.* [*Acanth*] *rotomagensis*	20	IV. & III
	2	Soft grey marl with *Plocoscyphia*	10	II.
	1	Glauconitic marl with *Stauronema*	16	I.
			193	

STRATIGRAPHICAL DETAILS.

Zone of Ammonite varians.

(Chloritic Marl and Chalk Marl.)

Bed 1.—*Subzone of Stauronema Carteri.*—Resting on the marly clay of the Upper Gault is a bed of glauconitic marly sand and sandy marl, consisting largely of glauconite grains with some quartz sand and a varying amount of marly material. The basal part is of a dark green colour, and may be termed an earthy greensand or glauconitic sand-rock, for the proportion of marly matrix is small, but sufficient to bind together the sandy ingredients into a coherent mass. Its base is piped into the underlying Gault—that is to say, the top of the Gault is penetrated by a number of small and irregular pittings and borings which are 3 or 4 inches deep and are filled with the material of the overlying sand. There are no phosphate nodules at the junction, nor are there any higher up in the bed.

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* See Quart. Journ. Geol. Soc., Vol. xlii. p. 225, and subsequent descriptions in this memoir.

Upwards the proportion of sand diminishes and that of the marly matrix increases, but it continues to be distinctly green and sandy for a distance of about 16 feet, when it shades off rapidly into the next bed (2). The upper part is a green, sandy glauconitic marl with irregular spots and veinings of whiter marl. It it sufficiently coherent to weather along vertical joints into blocks of irregular prismatic shapes.

From the constant slips it is not easy to measure the thickness of this bed, but it is best exposed below the small outlier of Chalk Marl on which Martello Tower No. 3 stands. Dr. Fitton estimated its thickness here as "about 14 feet;"* Mr. Topley thought that "it may be 15 feet thick;"† Mr. Price, describing it in 1877, says it is about 14 feet,‡ but that "it is extremely difficult to obtain an accurate measurement." Mr. R. Kerr, chanced to have a good opportunity of measuring it in 1887, and found it to be 16 feet.

Fossils are not abundant in this bed, but the two sponges *Stauronema Carteri* and *Plocoscyphia labrosa* and the bivalve *Avicula gryphæoides* can generally be found. *Ammonites* [*Schloenbachia*] *varians* and *Scaphites æqualis* have been found, but are rare. *Pecten asper* has never been found.

This bed was formerly regarded as a representative of the true Upper Greensand, and was treated as such in Mr. Topley's Geology of the Weald (1875), and by Professor Barrois in his Recherches sur le Terrain Crétacé (1876, Table, p. 168). In 1877, however, Mr. F. G. H. Price dissented from this view, and wrote as follows:—"Upon carefully examining this bed, in company with Dr. Charles Barrois, of Lille, I have come to the conclusion that the Upper Greensand is wanting in the south-east of England (unless it be represented palæontologically by the Upper Gault, Beds X. and XI., zone of *Ammonites rostratus*), and that the dark green sandy deposit just now described forms the basement-bed of the Chalk Marl, they being palæontologically the same." (Op. cit., p. 436.)

In 1878 Professor Barrois also expressed his change of view; he separated its equivalent in France from the zone of *Pecten asper* and called it the zone of *Ammonites laticlavius*. He remarks, "this zone of *Am. laticlavius* corresponds exactly with the bed which I have followed throughout England under the name of *Chloritic*

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* Trans. Geol. Soc., Ser. 2, Vol. iv. p. 107, 1836.

† Geology of the Weald, p. 152. Mem. Geol. Survey, 1875.

‡ Quart. Journ. Geol. Soc., Vol. xxxiii. p. 433, 1877.

Marl: I agree then with the recent opinion of Messrs. Jukes Browne * and Price, who consider the zone of *Pecten asper* to be wanting in the Folkestone cliffs. The zone of *Ammonites laticlavius* (Bed I. with *Stauronema Carteri* of Mr. Price) there rests directly on the grey marl with *Ammonites inflatus*."

Bed 2.—*Subzone of Plocoscyphia labrosa.*—This bed is about 10 feet thick, and consists of rather hard and somewhat sandy chalk of a light grey colour. It contains large grains of glauconite near its base, where it passes down into Bed 1, but only grains of microscopic size in the rest of its mass. It includes three or four bands of hard chalk, which are full of the two sponges, *Plocoscyphia labrosa* (=*mœandrina*) and *Pl. fenestrata*, and Dr. Barrois has designated the horizon here and elsewhere by the name of the former.

This bed contains many fossils belonging to a considerable number of species (see list on p. 42), among which the following are common: *Holaster lævis* var. *nodulosus*, *Ostrea frons*, *Inoceramus striatus*, *Lima globosa*, *Plicatula inflata* and *Am.* [*Acanthoceras*] *Mantelli*.

Bones of *Ichthyosaurus campylodon* and of *Acanthopholis horridus* have been found in this bed, and Mr. Price has observed that those of *Ichthyosaurus* only occur in the hard sponge beds. Mr. Price also mentions the occasional occurrence of hard concretionary nodules, more or less incrusted with iron pyrites and bearing the appearance of having been rolled and waterworn, with small *Ostreæ* and *Plicatulæ* attached to them.

Bed 3. (III. and IV. of Price).—This includes the beds numbered by Mr. Price as III. and IV. because we do not see any good reason for so separating them, as most of the fossils which occur in the one occur also in the other.

The total thickness of this subdivision is from 19 to 20 feet. *Ammonites* [*Schlœnbachia*] *varians* occurs throughout.

The lower 8 or 8½ feet (Mr. Price's Bed III.) consist of soft grey marly chalk, mottled in lighter and darker tints, and containing some lines of hard nodules. *Am.* [*Acanthoceras*] *rotomagensis* first occurs in this bed, and small fish-teeth are not uncommon belonging to *Corax falcatus*, *Notidanus microdon* and *Oxyrhina Mantelli*.

The next 8 feet consist of light grey marly chalk, in which *Radiolites Mortoni* occurs.

The highest 3 feet consist of three well-marked bands each about a foot thick; the first consists of very hard light grey chalk, poor in organic remains; the second is a soft dark grey marly chalk with many fossils; the third is a hard bed like the first. In the middle bed large specimens of *Ammonites* [*Acanthoceras*] *rotomagensis*, *Am.* [*Acanthoceras*] *Mantelli*, and a species like *Am.* [*Haploceras*] *lewesiensis* occur. A variety of *Pecten elongatus* is also found in this layer.

Bed 4. (V. of Price).—This is the Bed V. of Mr. Price, and is only a thin bed, being less than 3 feet in thickness, but is of importance on account of the number and variety of the fossils which it contains. Mr. Price describes it as a soft chalk-marl of a light grey colour, mottled and striped with darker grey, and, as it is soft enough to be cut with a knife, its fossils can be easily extracted. It is sometimes known as the "cast-bed."

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* Geol. Mag., Dec. ii, Vol. iv. p. 364.

This bed rises above high water level at a point about two miles east of Folkestone, and the place is marked by the issue of a strong perennial spring, which is known as Lydden Spout. This outflow of water is evidently due to the impermeability of this compact argillaceous marl which forms a floor under the hill behind, and holds up the water which has percolated through the superincumbent chalk.

Small nodules of iron pyrites occur in this bed which have a smooth, bright, silvery surface, and thus differ from the nodules occurring in other beds.

Although this bed is rich in fossils, and has yielded many species which have not yet been found in the beds below, yet the fauna is essentially that of the Chalk Marl or zone of *Ammonites varians*, and most of the Cephalopoda which occur in it are also found in Bed 2. What gives it, however, a distinctive character is the number of Gastropoda it contains; no fewer than nineteen species having been recorded by Mr. Price. There are also many small Brachiopods *Rhynchonella mantelliana* and *Terebratulina nodulosa* being especially common.

Bed 5.—This, together with the succeeding Beds 6, 7 and 8, make up the division which was numbered VI. by Mr. Price. Above the band which has been indicated as the "cast-bed" of Price there are 19 feet of grey marly chalk, which we are inclined to class as "Chalk Marl" rather than "Grey Chalk." The abundance of *Rhynchonella mantelliana* and the occurrence of *Am.* [*Schloenbachia*] *varians* link it to the beds below rather than to those above.

The lowest 2 feet consist of rather firm grey chalk less marly than the remainder.

Above this are 7 feet of dark grey marly chalk containing fragments of *Am. varians*.

The remaining 10 feet consist of rather soft grey marly chalk containing *Rhynchonella mantelliana, Rh. Martini, Kingena lima*, and other fossils.

There is no definite demarcation between this and No. 6.

Zone of Holaster subglobosus.

Bed 6.—This subdivision consists of what may legitimately be called "grey chalk," in contrast with the marly chalk below and the whiter chalk above. It is massive and blocky, breaking rather along curvilinear joint-planes than along definite lines of bedding;

by piecing on the beds seen at Baker's Harbour west of Shakespeare's cliff to higher beds seen at the western entrance of the tunnel it appears to be divisible into three portions which in descending order are as follows :—

	ft.
Yellowish-grey chalk, massively bedded ; seen for - - -	23
Grey chalk with large patches or mottlings of yellowish-grey (top not seen) - - - - - - - - - -	21
Massive grey blocky chalk, with *Rhynchonella Grasiana*, *Discoidea subuculus*, etc. - - - - - - - -	16

Mr. Rhodes obtained many fossils from the middle part, including *Holaster subglobosus*, *Hol.trecensis*, *Cidaris Bowerbanki* (spines), *Pseudodiadema ornatum*, *Ps. Normaniæ* and *Pecten Beaveri*.

Bed 7.—This bed was recognised by Mr. Whitaker and mentioned in his "Geology of the London Basin" (1872), p. 33. Writing of the "Grey Chalk" as defined by Phillips, he says, "Near the top there is a more massive bed, about 8 feet thick, which at Hay Cliff has small hard projections, some being pyrites, some fossils, and others stony lumps." By Mr. Hill's measurement 7 feet is the thickness, but it may be a little over, and the material may be described as greyish-white chalk in thin beds containing hard, flattish lenticular lumps or knobs of hard stony chalk, which weather out prominently. Large Ammonites occur in this bed, one of which was taken to Jermyn Street and identified as *Am.* [*Acanth.*] *rotomagensis*.

Bed 8.—This is the subdivision called by W. Phillips, "chalk without flints and with few organic remains." He describes it as forming the base of Shakespeare's cliff rising from the beach at the eastern end of that cliff, and as traversed by tranverse or vertical joints which give this chalk "an angular appearance, not common to any other parts of the cliff."

It is a soft whitish chalk, and, as Phillips remarked, it contains very few fossils ; *Discoidea cylindrica* and a few fragments of a *Holaster*, either *trecensis* or *subglobosus*, were the only fossils found by us, but Mr. Price mentions palates of *Ptychodus polygyrus* and *P. decurrens* as found towards the top of his Bed VI. Nodules of iron pyrites, some spherical and some cylindrical, are common, and are of a dark colour externally. Our estimate of 53 feet closely agrees with that of Phillips', who gives "about 50 feet" as its thickness.

Bed 9 (Bed VII. of Price).—This is the soft marl of W. Phillips dividing "the whiter and softer chalk" from the "hard yellowish" chalk above ; and it is the bed which Mr. Whitaker describes as about 6 feet thick and containing Belemnites.* Mr. Price's account of it is not clear, because he describes it as "yellowish, gritty, white chalk," and in referring to Mr. Whitaker's Memoir, he quotes the description of a very different bed at a lower horizon, that namely which separates the grey from the white chalk, *i.e.*, our Bed 7.

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*Mem. Geol. Survey, Vol. iv. p. 33. (1872).

In reality the bed consists of soft yellowish-grey or buff-coloured marl, and it separates the smooth white-jointed chalk of Bed 8 from the nodular yellowish-white gritty chalk which represents the Melbourn Rock. It is the Belemnite Marl of our nomenclature (p. 20).

Actinocamax plenus is not uncommon in this marl, but other fossils are rare, the only species recorded by Mr. Price being *Ptychodus decurrens, Pty. polygyrus* and *Plicatula inflata.*

The following is a list of the fossils which have been obtained from the several beds or subdivisions of the Lower Chalk between Folkestone and Dover. The list is based on that given by Mr. Price, the fossils entered on his authority being indicated by the letter P; those obtained by the Survey collector are marked S; a few (marked B) are quoted from Professor Barrois' paper on the Boulonnais,* and are credited to our Bed 6, though one or two may have come from No. 5. These species were identified by M. Cotteau.

FOSSILS FROM THE LOWER CHALK NEAR FOLKESTONE.

——	Zone of Am. varians.					Zone of H. subglobosus.			
	Bed 1.	Bed 2.	Bed 3.	Bed 4.	Bed 5.	Bed 6.	Bed 7.	Bed 8.	Bed 9.
Spongida.									
Hylospongia sp.	P	–	–	–	–	–	–	–	–
Plocoscyphia fenestrata, *Mant.*	–	P	–	–	–	–	–	–	–
„ labrosa, *Smith* (=mæandrina	P	P	–	–	–	–	–	–	–
Stauronema Carteri, *Sollas*	P	–	–	–	–	–	–	–	–
„ lobata, *Sollas*	P	–	–	–	–	–	–	–	–
Ventriculites sp.	–	P	–		–	–	–	–	–
Actinozoa.									
Micrabacia coronula, *Goldf.*	–	P	–	P	S	S	–	–	–
Echinodermata.									
Cidaris Bowerbanki, *Dixon*	–	–	–	–	–	S	–	–	–
„ dissimilis, *Forbes*	–	–	–	P	–	–	–	–	–
„ vesiculosa, *Goldf.*	–	P	P	–	–	P?	–	–	–
„ sp.	–	–	–	–	–	S	–	–	–
Discoidea cylindrica, *Lam.*	–	–	–	–	–	–	–	S	–
„ subuculus, *Klein*	–	E	P	–	–	S	–	–	–
Echinocyphus difficilis, *Forbes*	–	–	–	–	–	B	–	–	–
Epiaster crassissimus, *d'Orb.*	–	–	–	P	–	–	–	–	–
Goniaster (Calliderma) mosaicus, *Forbes*	–	–	–	P	–	P	–	–	–
„ sp.	–	–	P	–	–	S	–	–	–
Hemiaster Morrisi, *Forbes*	–	–	–	P	–	B	–	–	–
„ Griepenkerli, *Stroembeck*	–	–	–	–	–	B	–	–	–
Holaster lævis, *Ag.* (var. nodulosus)	–	P	–	–	–	S	–	–	–
„ subglobosus, *Leske*	–	–	–	–	–	S	–	?	–
„ trecensis, *Leym.*	–	–	–	–	–	S	–	S	–
Ophiura ?	–	–	–	–	–	P?	–	–	–
Peltastes clathratus, *Ag.*	–	E	–	P	–	B	–	–	–
„ umbrella, *Ag.*	–	E	–	?	–	–	–	–	–
Pseudodiadema Michelini, *Desor*	–	–	–	–	–	B	–	–	–
„ Normaniæ, *Cott.*	–	–	–	–	–	S	–	–	–
„ ornatum, *Goldf.*	–	–	–	P	–	S	–	–	–
„ pseudo-ornatum, *Cott.*	–	–	–	–	–	B	–	–	–
„ variolare, *Brongn.*	–	–	P	P	–	B	–	–	
„ sp.	P	–	–	–	–	–	–	–	–
„ sp.	–	–	–	P	–	–	–	–	–
Salenia Austeni, *Forbes*	–	–	–	S	–	–	–	–	–
„ Clarkii, *Forbes*	–	–	–	P	–	–	–	–	–
„ petalifera, *Desm.*	–	–	–	S	–	–	–	–	–

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* Proc. Geol. Assoc., Vol. vi. p. 29,

Fossils from the Lower Chalk near Folkestone.—*cont.*

———	Zone of Am. varians.					Zone of H. subglobosus.			
	Bed 1.	Bed 2.	Bed 3.	Bed 4.	Bed 5.	Bed 6.	Bed 7.	Bed 8.	Bed 9.
Annelida.									
Serpula annulata, *Reuss*	S	P	P	–	S	S	–	–	–
„ rustica, *Sow.*	S	–	–	–	–	–	–	–	–
„ planorbis, *Gein.*	–	–	–	–	–	S	–	–	–
„ umbonata, *Sow.*	–	–	–	P	–	S	–	–	–
Crustacea.									
Enoploclytia sussexensis, *Mant.*	–	–	–	P	–	P ?	–	–	–
Hoploparia sp.	–	–	–	P	–	P ?	–	–	–
Palæga Carteri, *Woodward*	–	–	–	P	–	–	–	–	–
Pollicipes glaber, *Roemer*	–	P	–	P	–	–	–	–	–
„ sp.	–	–	–	–	–	S	–	–	–
Brachiopoda.									
Kingena lima, *Defr.*	–	–	–	P	S	S	–	–	–
Rhynchonella grasiana, *d'Orb.*	S	–	–	P	–	S	–	–	–
„ mantelliana, *Sow.*	–	–	P	P	S	–	–	–	–
„ Martini, *Mant.*	–	–	–	P	S	–	–	–	–
„ sp.	–	–	–	–	–	–	–	–	–
Terebratula biplicata, *Sow.*	–	P	–	–	S	S	–	–	–
„ obesa, *Sow.*	–	P	–	–	–	–	–	–	–
„ semiglobosa, *Sow.*	–	–	–	–	–	S	–	–	–
„ squamosa, *Mant.*	–	–	–	P	S	S	–	–	
Terebratulina nodulosa, *Eth.*	–	–	–	P	–	–	–	–	
„ striata, *Wahl.*	–	–	–	P	–	S	–	–	
Lamellibranchiata.									
Arca carinata, *Sow.*	–	–	–	P	–	–	–	–	–
Avicula gryphæoides, *Sow.*	P	–	–	P	–	–	–	–	–
Cucullœa glabra (?) *Park.*	–	P	–	P	–	–	–	–	–
„ nana, *Leym*	–	–	–	P	–	–	–	–	–
Cardita tenuicosta, *Sow.*	–	–	–	P	–	–	–	–	–
„ sp.	–	P	–	–	–	–	–	–	–
Exogyra conica ? *Sow.*	S	–	–	–	–	–	–	–	–
„ haliotoidea, *Sow.*	–	–	–	P	–	–	–	–	–
„ var. Rauliniana, *d'Orb.*	–	–	–	P	–	–	–	–	–
Inoceramus striatus, *Sow.*	P	P	–	–	–	–	–	–	–
Inoceramus sp. (? Cripsi, *Mant.*)	P	–	–	–	–	–	–	–	–
Lima aspera, *Mant.*	–	–	–	P	–	–	–	–	–
„ globosa, *Sow.*	P	P	–	P	–	–	–	–	–
„ elongata, *Sow.*	S	P	–	P	–	–	–	–	–
„ sp.	–	P	–	–	–	–	–	–	–
Mytilus	–	–	–	P	–	–	–	–	–
Nucula pectinata, *Sow.* (var. cretæ)	–	–	–	P	–	–	–	–	–
Ostrea frons, *Park.*	S	P	–	–	–	–	–	–	–
„ normaniana, *d'Orb.*	–	–	–	P	–	–	–	–	–
„ vesicularis, *Lam.*	P	–	–	–	–	S	–	–	–
Pecten Beaveri, *Sow.*	–	P	P	P	–	S	–	–	–
„ arlesiensis, *Woods.*	–	P	–	–	–	–	–	–	–
„ elongatus, *Lam.*	–	P	P	P	P ?	–	–	–	–
„ „ var.	–	–	P	–	–	–	–	–	–
„ orbicularis, *Sow.*	P	P	P	P	S	–	–	–	–
„ (Neithea) quadricostata, *Sow.*	–	–	–	P	–	–	–	–	–
„ „ quinquecostata, *Sow.*	S	P	–	P	P ?	–	–	–	–
Pleuromya sp.	–	–	P	–	–	–	–	–	–
Pholadomya decussata, *Phil.*	–	–	–	P	–	–	–	–	–
Plicatula inflata, *Sow.*	P	P	–	P	S	–	–	–	P
„ pectinoides, *Sow.*	P	P	–	P	–	–	–	–	–
„ sigillina, *Woodward*	–	P	–	P	–	–	–	–	–
Radiolites Mortoni, *Mant.*	–	–	P	–	–	–	–	–	–
Spondylus dutempleanus, *d'Orb.*	–	P	–	–	–	–	–	–	–
„ latus, *Sow.*	–	P	–	–	–	–	–	–	–
Gasteropoda.									
Aporrhais Mantelli, *Gard.*	–	–	–	P	–	–	–	–	–
„ doratochila, *Gard.*	–	–	–	P	–	–	–	–	–
„ opeatochila, *Gard.*	–	–	–	P	–	–	–	–	–
„ spathochila, *Gard.*	–	–	–	P	–	–	–	–	–
„ (Ornithopus) oligochila, *Gard.*	–	–	–	P	–	–	–	–	–
„ „ pachysoma, *Gard.*	–	–	–	P	–	–	–	–	–
Cerithium lallierianum ? *P. & C.*	–	–	–	P	–	–	–	–	–
(like trimonile, *Mich.*)	–	–	–	P	–	–	–	–	–
Dentalium majus, *Gard.*	–	–	–	P	–	–	–	–	–

Fossils from the Lower Chalk near Folkestone.—*cont.*

———	Zone of Am. varians.					Zone of H. subglobosus.			
	Bed 1.	Bed 2.	Bed 3.	Bed 4.	Bed 5.	Bed 6.	Bed 7.	Bed 8	Bed 9.
Emarginula Gresslyi, *P. & C.*	–	–	–	P	–	–	–	–	–
Fusus sp	–	–	–	P	–	–	–	–	–
Natica sp.	–	P	–	P	–	–	–	–	–
Pleurotomaria perspectiva, *Mant.*	–	P	–	–	–	–	–	–	–
,, sp.	–	–	–	P	–	–	–	–	–
Rostellaria Pricei, *Woodward*	–	–	–	P	–	–	–	–	–
Scalaria dupiniana, *d'Orb.*	–	–	–	P	–	–	–	–	–
Solarium, sp.	–	P	–	P	–	–	–	–	–
Turbo Triboleti, *P. & C.*	–	–	–	P	–	–	–	–	–
Turritella	–	–	–	P	–	–	–	–	–
Voluta semiplicata, *Mant.*	–	–	–	P	–	–	–	–	–
Cephalopoda.									
Ammonites (Acanth.) cenomanensis, *d'Arch.*	–	P	–	P	–	–	–	–	–
,, (Hoplites) falcatus, *Mant.*	–	P	–	–	–	–	–	–	–
,, (Haploc.) lewesiensis (?), *Mant.*	–	–	P	–	–	–	–	–	–
,, (Acanth.) Mantelli, *Sow.*	–	P	P	–	–	–	–	–	–
,, (,,) ,, var. navicularis, *Mant*	–	P	–	–	–	–	–	–	–
,, (,,) rotomagensis, *d'Orb.*	–	–	P	P	–	–	S	–	–
,, (Schloenb.) varians, *Sow.*	P	P	P	P	S	–	–	–	–
,, (,,) Coupei, *Brongn.*	–	–	–	P	–	–	–	–	–
,, sp.	–	–	–	–	P	–	–	–	–
Scaphites æqualis, *Sow.*	P	P	–	–	–	–	–	–	–
Turrilites costatus, *Sow.*	–	P	–	P	P?	–	–	–	–
,, scheuchzerianus, *Bosc.*	–	P	–	–	–	–	–	–	–
,, tuberculatus, *Bosc.*	–	P	–	–	–	–	–	–	–
Ancyloceras sp.	–	–	–	P	–	–	–	–	–
Actinocamax lanceolatus *Sow,*	–	–	–	P	–	–	–	–	–
,, ,, plenus, *Blainv.*	–	–	–	–	–	–	–	–	P
Nautilus deslongchampsianus, *d'Orb.*	–	–	–	P	–	–	–	–	–
,, elegans, *Sow.*	–	P	–	P	–	–	–	–	–
,, sp.	P	P	–	–	–	–	–	–	–
Pisces.									
Corax falcatus, *Ag.*	–	–	P	–	–	–	–	–	–
Edaphodon	–	P	–	–	–	–	–	–	–
Ischyodus	–	–	–	P	–	–	–	–	–
Lamna appendiculata, *Ag.*	P	–	–	P	–	–	–	–	–
Macropoma	–	–	–	P	–	–	–	–	–
Notidanus microdon, *Ag.*	–	–	P	–	–	–	–	–	–
Oxyrhina Mantelli, *Ag.*	–	–	P	–	–	–	–	–	–
Pachyrhizodus Gardneri, *Mason*	–	X	–	–	–	–	–	–	–
Pisodus	–	–	–	P	–	–	–	–	–
Ptychodus decurrens, *Ag.*	–	–	–	–	–	–	–	P	P
,, polygyrus, *Ag.*	–	–	–	–	–	–	–	P	P
Protosphyræna ferox, *Leidy*	–	P	–	–	–	–	–	–	–
Scapanorhynchus subulatus, *Ag.*	–	–	–	P	–	–	–	–	–
Vertebræ, coprolites, etc	–	P	–	P	–	–	–	–	–
Reptilia.			–						–
Acanthopholis horridus, *Huxley*	–	P	–	–	–	–	–	–	–
Acrodontosaurus Gardneri, ***Hulke*** (See Pachyrhizodus under *Pisces)*	–	–	–	–	–	–	–	–	–
Ichthyosaurus campylodon, *Carter*	P	P	–	–	–	–	–	–	–

CHAPTER IV.

THE LOWER CHALK IN THE INLAND PARTS OF KENT AND IN SURREY.

1. KENT.

General Description.

Having now given full particulars of the coast section between Folkestone and Dover, we shall notice some of the sections in the Lower Chalk along the course of its outcrop through Kent.

So far as we can judge, its total thickness does not diminish westward; but there is little accurate information on this point, for, although it has been traversed by several borings, the published accounts of these do not give any certain indication of the summit of this division. Mr. Whitaker, however, examined some samples from the lower part of the boring at Chatham Dockyard (Well No. 1),* and from the particulars given by him the Lower Chalk there appears to be 191 feet thick, or only 2 feet less than at Dover.

We may therefore assume that its several parts maintain much the same thickness as they exhibit in the coast section, exception being made in regard to the Chloritic Marl, or zone of *Stauronema*, which rapidly diminishes in thickness inland.

The general features of the coast section are repeated inland, and wherever good sections occur the descending succession is always found to be as follows:—

Marl with *Actinocamax plenus* - =Bed 9.
Massive white chalk - - - =Bed 8.
Massive grey chalk - - - =Beds 6 and 7.
Chalk marl with layers of hard chalk=Beds 2, 3, 4, and 5.
Thin bed of glauconitic marl.

The bed of marl at the top is everywhere conspicuous, and the characteristic fossil may be found in nearly every exposure of it.

The white chalk below seems to keep about the same thickness as at Dover, but it is not always so sharply marked off from the grey. In the western part of the county it passes down gradually through greyish-white into grey chalk. When quarried these massive grey and white beds generally split into large angular blocks, but in the lower part the fracture is frequently conchoidal.

The Chalk Marl does not seem to change materially in its westward course, but the exposures of it are few and far between.

It will be convenient to trace the course, first of the basement bed, then of the Chalk Marl, and finally of the higher zones.

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* Quart. Journ. Geol. Soc., Vol. xlii. p. 29, 1886.

Zone of Ammonites varians.

Chloritic Marl. The more sandy part of the sub-zone of *Stauronema* does not extend far in from the coast. Mr. Topley observes that "10 feet of rather clayey and calcareous Greensand are exposed in the cutting just east of Folkestone Junction Station, at the west end of Martello Tunnel; there is soft Chalk Marl above, with a few green grains in the lower part. In the heaps of earth above the tunnel-mouth much Greensand may be seen, some hard and with nodules."*

It is seen again at the foot of Castle Hill in the most easterly of the roads which unite there and just north of their junction, but Mr. Topley states that "it is here only 3 or 4 feet thick, and contains many small phosphatic nodules."

West of this point the *Stauronema* zone appears to thin out entirely, for Mr. Simms, writing in 1844, says it does not occur at the foot of Tolsford Hill, "the only trace of it being some grains of sand mixed with the Chalk Marl over the Gault;"† and Mr. Topley says, "still further west, as in the road north of Stanford, I have not been able to find any." (Op. cit., p. 154.)

It is rather remarkable that a bed which is so conspicuous at Folkestone should thin out so rapidly, for in most other parts of the south of England it is a fairly constant band.

We did not find any exposures of the base of the Chalk between Wye and Aylesford, but a note by Prof. T. McK. Hughes, quoted by Mr. Topley,‡ states that a thin bed of dark Greensand occurs above the Gault near Charing, that such material was turned out of some deep drains east of Charing and was again touched near Eastwell

In the brickyard at Aylesford, north-east of Maidstone, there is a thin bed of sandy glauconitic marl at the base of the Chalk (see section given in Vol. I., p. 88). The same bed is also seen in the cutting made for the tramway leading from the Burham brickyard to the large quarries in the Chalk half a mile east of Burham. It is not certain, however, that this bed really represents the zone of *Stauronema Carteri*, as that fossil has not been found in it.

The outcrop of this glauconitic marl forms a low ridge in the bed of the river Medway between Burham and Snodland, but is only visible at low water.

Further west it can be seen in the right bank of the watercourse issuing from a spring at Coney Hall Farmstead, half a mile south of Birling House. From this point to just east of Kemsing it is hidden. Immediately west of Kemsing it begins to regain importance, and becomes still thicker to the westward.

"Green marly sand below the Chalk" was seen by Mr. Topley in the railway cutting south of Otford. At the spring-head near New Barns Farmstead, about a mile W.S.W. of Otford Church,

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* Geology of the Weald, Mem. Geol. Survey, 1872, p. 152.

† Proc. Geol. Soc., Vol. iv. p. 206.

‡ Geology of the Weald, Mem. Geol. Survey, 1872, p. 152.

4 to 5 feet of greyish-white marly chalk is exposed, containing (*Ammonites varians,* and *Am. Coupei*), and beneath it is soft buff-grey marl. Following the stream downwards, the glauconitic sandy marl is found with a thickness of 5 feet at least; its junction with the chalk is not seen, nor is that with the Gault easily traced, but the impression conveyed by a succession of specimens brought up by a hand-augur was that the glauconitic bed passed gradually to the Gault without a well-marked base line.

Chalk Marl—There do not appear to be many quarries in this part of the Lower Chalk in Kent. Portions of it are shown occasionally in road cuttings, but we have not been able to examine the course of outcrop in sufficient detail to trace the minor beds of the coast section inland.

Two or three miles east of Wye hard beds occur low down in the Chalk Marl, apparently rather nearer the base than at Folkestone, but this may be partly due to the thinning of the *Stauronema* zone. They are seen in the lane leading from the main road to Bull Town Farm, and they yielded *Am.* [*Schloenbachia*] *varians, Scaphites æqualis, Terebratula biplicata, Pecten orbicularis,* and *Plicatula inflata.*

Shallow cuttings at Giddy Horn Wood, Cocklescombe, and Newgate Scrubs show the same beds.

The best inland section is probably that in the cutting which leads from the brickyard at Burham to the large quarry half a mile east of Burham. The basement bed is seen at the entrance of the cutting, and further on beyond the tunnel the following section was taken by Mr. W. Hill in 1896:—

	feet.
Greyish chalk, slightly yellowish or buff-coloured, much broken up and inaccessible, - - - - - - - over	20
Greyish-buff chalk with three or four hard beds - - -	10
Soft bluish-grey marl - - - - - - - - -	6

The sides of the cutting are very steep, so that the upper part was inaccessible, but portions weathered out as if harder than the rest.

In a quarry about 200 yards south of the Black Horse Inn at Thornham 20 feet of the Lower Chalk is seen, very much broken up, as usual.

Zone of Holaster subglobosus.

Numerous small quarries along the base of the North Downs east of Wye show the highest part of the Lower Chalk.

At the Lime Kiln, one-third of a mile east of Coldharbour Farm, about two miles east of Wye, the section was:—

		ft.	in.
	Soil, etc. - - - - - - - - - - -	1	0
Part of Bed 8.	Rather rubbly whitish chalk, inclined to weather in platy flakes - - - - - - - - -	10	0
	Blocky whitish chalk - - - - - - -	15	0
? Bed 7.	A well-marked layer of cream-coloured nodules, brown exteriorly, in grey marl - - - - - - -	0	8
Bed 6.	Firm greyish-white chalk in massive courses - -	18	0

The numbers prefixed indicate the probable correlation with the beds of the coast section. The layer of nodules occurs at the same horizon as Bed 7 on the coast, but the nodules more resemble those which occur at Litlington, in Cambridgeshire, at about the same horizon (see p. 199). There is a small pit one-third of a mile north-east of Harrietsham, near St. John the Baptist's Church, which shows 15 feet of soft grey marly chalk; the rock is much broken up, and is merely rubble. A fragment of *Ammonites* [*Acanthoceras*] *rotomagensis* occurred in it.

The summit of the Lower Chalk is seen about 300 yards south of All Saints' Church, Boughton Court. The section seen in 1896 was as follows:—

		ft.	in.
	Soil and rubble	2	0
Melbourn Rock.	Hard cream-coloured nodular rock, much broken	5	0
	A course of smooth white hard rock 1 ft. to	0	9
Bed 9. Belemnite Marl.	Bed of grey laminated marl with *Act. plenus*	0	6
	Hardish white smooth chalk 1 ft. to	1	3
	Grey laminated marl	0	9
	Grey marly chalk	2	0
	passing down to		
Bed 8.	Firm greyish-white chalk seen for 14 ft. to	16	0

A similar section was seen at the excavation for rifle-butts about half a mile north of Greenway Court and three-quarters of a mile E.S.E. of Hollingbourne. Details of the stratification at this horizon, however, vary at different points—*e.g.*, at a small roadside quarry just north of the guidepost at the cross roads near Cobham Farm 1¼ mile N.N.E. of Boarsted the section below the soil was:—

		ft.	in.
Melbourn Rock.	Hard white rough chalk, rather broken	4	0
Bed 9.	Grey laminated marl, with discontinuous lenticular beds of hard white smooth chalk—*Actinocamax plenus*, *Rhynch. plicatilis*	2	0
Bed 8.	Firm greyish marly chalk, passing down to greyish-white blocky chalk	14	0

It will be seen that the Belemnite marls are not so well developed here as at most other places.

The top of the Lower Chalk with the *Belemnite marl* is exposed again in the lane leading to Boarley.

The large pits at the upper part of the Valley of the Medway, between Aylesford and Wouldham on the right bank, and in the neighbourhood of Halling on the left bank, all show good sections of the upper part of the Lower Chalk. The details vary but little. We select the two which give the clearest sections.

That of Wouldham Hall quarry, belonging to Messrs. Peters and Co., is as follows:—

			ft.	in
Middle Chalk.		Soil and rubble	2	0
		Firm white chalk	8	0
		Hard rough whitish chalk, scarcely nodular, containing *Rhynch. Cuvieri*	6	0
	Melbourn Rock. 6½ft.	Rough nodular chalk much broken	2	0
		Very hard nodular chalk; the nodules in both the above courses are creamy yellow	2	0
		Very hard nodular chalk, whiter than that above, much streaked with green-grey marl	2	6
Lower Chalk.	Belemnite Marl.	Marly chalk weathering into thin laminæ, with lenticular beds of hard white chalk, very variable in thickness—*Actinocamax plenus*, 1 ft. 3 in. to	2	6
		Firm greyish-white marly chalk, the base sometimes marked by a thin marl seam, 4 ft. to	5	0
		Whitish chalk, firm and blocky, gradually passing to grey hard chalk - about	80	0

The quarries of the Burham Brick and Lime Company, situated nearly two miles east of the river Medway, and three-quarters of a mile E.S.E. of the village of Burham, afford an excellent series of exposures, for the whole succession from Upper Gault to the base of the Upper Chalk can be seen with the exception of a part of the zone of *Ammonites varians*.

There are two quarries. In the lower one, where the Lower Chalk is seen, the section taken in 1896 was:—

		ft.	in.
Middle Chalk and Melbourn Rock		30	0
Belemnite Marl	Greenish-grey laminated marl with lenticular beds of hard white chalk - - 1 ft. to	1	6
	Pale buffish-grey marly chalk, fracture often conchoidal—*Actinocamax plenus.*	6	0
Beds 6, 7 and 8.	Firm white chalk, passing gradually down to grey chalk—*Hol. subglobosus*, *H. trecensis*, *Terebratula biplicata* - about	80	0
Bed 5.	Grey marly chalk, *Rhynchonella mantelliana*, *Kingena lima*, *Am.* [*Acanth.*] *rotomagensis*, *Ter. semiglobosa*, and *Serpula umbonata*, about	15	0

The Belemnite marls are clearly exposed. In the upper marly band the lenticular beds of hard white chalk often predominate, the marl being subsidiary. The 6-foot bed beneath can be followed round the quarry, as it differs from the underlying chalk in having a laminated structure which is brought out by the weathering.

The grey chalk at the base is lower than that in the quarries nearer the Medway, and the presence of *Rhynchonella mantelliana* in some abundance is noteworthy; either this species ranges higher than at Folkestone, or else this marly chalk corresponds with that immediately overlying the "cast-bed" in the coast section. In the latter case, however, the zone of *Hol. subglobosus* must be thinner, and that of *Am. varians* thicker, than at Folkestone.

In the quarry close by Otford Station some 60 feet of the Lower Chalk is exposed. White or nearly so at the top, it passes down to grey marly chalk at the base, with *Rhynchonella mantelliana.* Cuttings on the railway one mile north of Otford Station also show the topmost of the Lower Chalk.

The following list of fossils from the Lower Chalk of Burham Wouldham, Holborough, and Cuxton, has been compiled mainly from one given by Mr. G. E. Dibley, supplemented by the record of a few specimens collected for the Geological Survey.

FOSSILS FROM THE LOWER CHALK OF THE MEDWAY VALLEY.

	Zone of Am. varians.	Zone of Hol. subgl.
Vertebrata.		
Apateodus striatus, *Ag.*		+
Beryx microcephalus, *Ag.* (Ctenothrissa)		+
Dercetis elongatus, *Ag.*		+
Enchodus sp.		+
Edaphodon Mantelli, *Buckl.*		+
„ sp.		+
Homonotus dorsalis, *Dixon*		+
Notidanus microdon, *Ag.*		+
Oxyrhina angustidens, *Reuss*		+
Pachyrhizodus Gardneri, *Mason*		+
„ sp.		+
Plethodus oblongus, *Dixon*		+
Portheus sp.		+
Protosphyræna sp.		+
Ptychodus decurrens, *Ag.*		+
„ depressus, *Dixon*		+
„ lævis, *A.S.W.*		+
„ polygyrus, *Ag.*		+
Tomognathus mordax, *Dixon*		+
Invertebrata.		
Ammonites [Acanthoceras] Mantelli, *Sow.*	+	
„ [„] rotomagensis, *Brongn.*	+	
„ [Schloenbachia] varians, *Sow.*	+	
„ [„] Coupei, *Brongn.*	+	
Turrilites costatus, *Lam.*	+	
„ tuberculatus, *Bosc.*	+	
Scaphites æqualis, *Sow.*	+	
„ obliquus, *Sow.*	+	
Hamites armatus, *Sow.* [Anisoceras]	+	
Baculites sp.	+	
Nautilus elegans ? *Sow.*	+	
„ deslongchampsianus, *d'Orb.*	+	
Actinocamax plenus, *Blainv.*		+
Solarium ornatum ? *Sow.*		+
Pleurotomaria perspectiva, *Mant.*		+
Arca sp.	+	
Exogyra haliotoidea ? *Sow.*		+
Lima aspera, *Mant.*		+
„ echinata, *Eth.*	+	–
„ elongata, *Sow.*		+
Inoceramus Cripsi ? *Mant.*		+
„ latus, *d'Orb.*, non *Mant.*	+	–
„ striatus, *Mant.*		+
Ostrea hippopodium, *d'Orb.*		+
Pecten Beaveri, *Sow.*		+
„ orbicularis, *Sow.*	+	+
„ fissicosta, *Eth.*		+
„ new sp.		+
Pinna decussata, *Goldf.*		+
Plicatula inflata, *Sow.*	+	+
Pleuromya sp.	+	
Pholadomya decussata, *Phil.*	+	+
Teredo amphisbæna, *Goldf.*		+
Terebratula biplicata, *Sow.*		+
„ semiglobosa, *Sow.*	+	+
„ squamosa, *Mant.*	–	+
Rhynchonella mantelliana, *Sow.*	+	+
„ dimidiata ? *Sow.*	+	
Kingena lima, *Defr.*	+	+
Enoploclytia Leachi, *Mant.*	–	+
„ sussexiensis, *Mant.*	–	+
Serpula ampullacea, *Sow.*		+
„ umbonata, *Sow.*	+	
Discoidea cylindrica, *Lam.*		+
Holaster subglobosus, *Leske*		+
„ trecensis, *Leym.*		+
Pseudodiadema ornatum, *Goldf.*		+
Axogaster cretacea, *Lonsd.*		+
Coniferous wood		+

2.—SURREY.

GENERAL DESCRIPTION.

The Lower Chalk of Surrey is a continuation of that of Kent, but its outcrop becomes much narrowed near Guildford, in consequence of the steeper inclination of the beds.

There is no well-marked basement bed to the Chalk of Surrey, except in the extreme west near Farnham. Everywhere between Godstone and Guildford the Selbornian sand passes up into a glauconitic sandy marl, and this into a soft chalky marl without glauconite. Part of this passage is doubtless to be regarded as representing the Chloritic Marl or zone of *Stauronema Carteri*, but as fossils are rare, and the usual brown phosphates are almost completely absent, it lacks the usual characteristics of that horizon.

The Chalk Marl above is of a greyish-buff colour, very soft at the base, but passing up into firmer greyish-white marl, succeeded by marly chalk with hard concretionary masses, in which *Am.* [*Schloenbachia*] *varians* is common. The central part of the stage consists of firm grey chalk, in which *Holaster subglobosus*, *Pecten Beaveri*, and a few other fossils occur.

The upper beds of the Lower Chalk present the same characters as those in Kent, being massive, blocky and whitish, till the marly chalk of the Belemnite band is reached.

The total thickness is probably about 200 feet. In the Streatham boring it was found to be 188½ feet; at Richmond it is stated to be 220 feet, and still further west, at Winkfield, it is 219 feet. The particulars obtained about this part of the Chalk in the Winkfield boring may be summarised as follow:—

	ft.	in.
White and green chalk (? Belemnite marls) - - - -	6	0
White chalk, some parts free-cutting, but most of it hard	105	9
Hard grey chalk, the lower part being of a dark grey colour	35	3
Blue and brown marly chalk - - - - - - -	22	0
Grey (? marly) chalk with hard layers from 1 to 13 inches thick - - - -	50	0
	219	0

The base was fixed by the examination of a sample from the depth of 939 feet, which showed the characters of the Chloritic Marl. If the description is to be trusted with regard to colour, the thickness of white chalk here is unusually great, but the succession of White Chalk, Grey Chalk, and Chalk Marl is clearly shown.

Zone of Ammonites varians.

Chloritic Marl.—The passage beds from Upper Greensand to the Chalk are well seen in the quarry at Colley Hill, near Reigate.

The section as seen in 1896 was given in the first volume of this memoir, but a part of it may be repeated here, as follows :—

		ft.
Chalk Marl.	Soil and rubbly Chalk	3
	Grey marly Chalk, drying whitish	6
	Grey mottled marly Chalk, containing hard concretionary lumps ; *Am.* [*Schloenbachia*] *varians*	9
	Grey clayey marl mottled with yellowish buff	2
Chloritic Marl.	Greyish-green sandy glauconitic marl, with *Ostrea vesicularis* and *Avicula gryphæoides*	3
Selbornian.	Micaceous marly sands	8½
	Grey sandstones (Hearthstone)	12

There is a complete passage here from Selbornian to Chalk through the bed which we regard as Chloritic Marl, and there are no phosphatic nodules. There is a similar succession at Betchworth (see below).

About 300 yards west of Whiteways End House, 2½ miles east of Farnham, a shallow but important section was seen in a small quarry as follows :—

		ft.	in.
	Soil	1	0
Chalk Marl.	Chalk Marl, soft, but with hard rubbly fragments —*Am.* [*Schloenbachia*] *varians*	1	6
Chloritic Marl.	Soft, very glauconitic sandy marl, with many brown phosphates,(a phosphate cast of *Avicula gryphæoides*)	1	0
Upper Greensand.—	Greyish-brown sandy marl	1	2

The grey sandy marl is quite different from that underlying the Chalk Marl to the eastward, but is identical with that underlying the Chloritic Marl in Hampshire, and the reappearance of phosphatic nodules is noteworthy.

Chalk Marl.—There are few exposures of the Chalk of this zone. Mr. Caleb Evans notices "dark grey Chalk Marl, and also blocks of yellowish Chalk," in the débris thrown out from the shafts of the tunnel north of Oxted Station.* He continues : "The light grey and yellowish chalk is hard, and shows little approach to marl. It contains in abundance casts of *Am.* [*Schloenbachia*] *varians* and of *Inoceramus*." The hard blocks were probably the concretionary masses near the base of the Chalk Marl.

A small disused quarry about a mile east of Merstham exposes greyish-white Chalk with *Am.* [*Schloenbachia*] *varians*. The section near Reigate has been given above.

The base of the Chalk Marl is also exposed in a quarry one-third of a mile north-east of Betchworth Station, close to the high road. In 1896 the section was as follows :—

		ft.	in.
Chalk Marl.	Soil and rubble	3	0
	Chalky rubble	2	0
	Marly chalk, very much broken up	4	0
	Marly whitish-grey chalk, with hard masses, disturbed and broken, *Am.* [*Schl.*] *varians*, *Am.* [*Schl.*] *Coupei*, *Turrilites costatus*, and *tuberculatus*	6	0

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* On some sections of the Chalk between Croydon and Oxted, Geol. Assoc., p. 27, January, 1870.

		ft.	in.
Chloritic Marl.	Buff-grey marly chalk, passing rapidly to grey very glauconitic marl; no division possible	3	6
Upper Greensand.	Firm grey-green glauconitic marly sand	10	0

The upper part of this zone is exposed at the bottom of the large quarries at Brockham, where a bed of hard, compact chalk has yielded *Am.*[*Schloenbachia*] *varians, Am.*[*Acanth.*] *rotomagensis,* and *Anisoceras armatus.*

Zone of Holaster Subglobosus.

The upper beds of the Lower Chalk, and the base of the Middle Chalk are seen at the northern entrance of the tunnel, between Warlingham and Oxted. Mr. Caleb Evans describes this chalk as the "Upper Marden Park Beds." The chalk seen in this cutting is chiefly the base of the Middle Chalk, but near the tunnel some 20 feet of the Lower Chalk is exposed. The sides of the cutting are not easily accessible, and the following section was taken by Mr. Hill a little distance north of the entrance to the tunnel:—

		ft.	in.
Middle Chalk.	Hard rough nodular chalk—Melbourn Rock	8	0
Subzone of *Actinocamax plenus.*	Yellowish-grey laminated marl, with lenticular beds of hard white chalk, *Actinocamax plenus*	1	0
	*Hard yellowish-grey marly chalk, weathering in thin platy pieces, with marly conchoidal fracture, *Actinocamax plenus*	3	6
Zone of *Holaster subglobosus.*	Firm whitish chalk, seen for about	10	0

The large Oxted quarries just east of the southern end of the tunnel show some 50 feet of the upper part of the Lower Chalk; but the Belemnite marl was not accessible at the time of our visit.

In the large quarries north of Merstham Station about 70 feet of the Lower Chalk is exposed. The Belemnite marls are seen about two-thirds of the distance up the quarry face, and below them is whitish chalk some 50 feet thick passing down to greyer and more marly chalk. The section is as follows:—

			feet.	in.
Middle Chalk.		Soil and rubbly chalk	3	0
		Firm white chalk (*Inoceramus mytiloides*) streaked and veined with greenish-grey, weathering along the veins into thin platy pieces (*Rhyn. Cuvieri*)	18	0
	Melbourn Rock.	A massive course of smoother chalk	2	0
		Hard rough nodular chalk, streaked and veined with green-grey marl	3	6
		A massive course of hard nodular rock nodules, creamy white, separated by veins of green-grey marl	2	0
Lower Chalk.	Subzone of *Act. plenus.*	Grey laminated marl, with lenticular layers of hard white chalk; the hard white material predominates in the lower part (*Actinocamax plenus* is common)	1	6
		Rather hard greyish-white marly chalk, weathering in thin laminæ, or platy pieces, fracture conchoidal (*Act. plenus*)	3	6
		Whitish chalk, for about	50	0
		Passing into greyer and more marly chalk, seen for	20	0

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* These sections were examined in very dry weather.

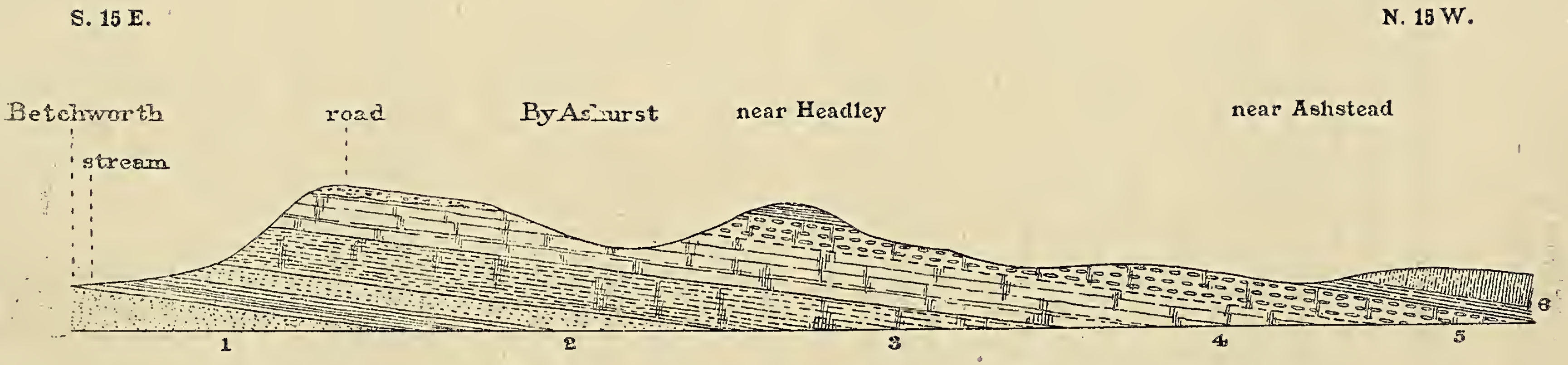

FIG. 26.—Section through the North Downs from Betchworth to near Ashstead.

Horizontal Scale 1 inch to one mile. Vertical Scale 1200 feet to an inch.

6. Eocene Beds.
4. Middle Chalk.
2. Selbornian (Gault and Malmstone.)
5. Upper Chalk.
3 Lower Chalk.
1. Lower Greensand.

Holaster subglobosus, Pecten Beaveri, Terebratula biplicata, Ter. semiglobosa, fish teeth, all occurred in the lower and greyer part of the Chalk. The Belemnite Marls, with some 50 or 60 feet of the Lower Chalk, can be seen at Messrs. Farrington's quarry at Reigate.

Another fine section through this zone occurs at the Dorking Greystone Company's pit at Betchworth Station. At the time of our visit the quarry presented a perpendicular face estimated about 175 feet, about half of which was in Lower Chalk. At the western corner of the quarry fresh workings exposed about 10 feet of the Lower Chalk and the Belemnite Marls. The marls here proved to be 10 feet thick; at the top was softish grey laminated marl, with lenticular beds of hard white chalk; the basal 8 feet were of solid massive character, breaking with well-marked conchoidal fracture. The characteristic fossil *Actinocamax plenus* was common.

Brockham quarry, which almost joins that of Betchworth, presents the same features, and has nearly as high a face.

A similar section occurs at the old Dorking limeworks, just north of Dorking Station. The Belemnite Marls are seen at the top of this quarry, which exposes 70 feet of Lower Chalk, the upper 45 to 50 feet nearly white, the lower part grey and more marly.

A long narrow quarry one mile west of Warren farm and 1½ miles south-east of Guildford, exposes Lower Chalk with the Belemnite Marls. The Chalk dips north at a very high angle, and no measurements could be taken. On the south side whitish chalk with several impressions of a large Ammonite occurred. On the north side there is similar chalk overlain by buff grey chalk with *Actinocamax plenus.*

The upper part of the Lower Chalk is exposed again at Seale Lime Works; about 35 feet of it are seen below the Belemnite Marls, which are here 5 feet thick.

Again, at the lower Victory quarry, three miles east of Farnham, the upper part of the Lower Chalk is seen, but though the Melbourn Rock occurs at the base of the upper quarry, and only a roadway separates the two pits, the Belemnite Marls are not exposed.

The following list of fossils must be regarded as merely a first attempt at a zonal list of the Lower Chalk fossils of Surrey, for though many good fossils have doubtless been obtained at various times, the only published list known to us is that by Mr. Caleb Evans. It is assumed that most of his "Lower Marden Park" fossils came from the zone of *Am. varians*, and to these have been added such fossils as were found by Mr. Hill and Mr. G. E. Dibley. Localities are indicated thus: *o*=Oxted, *b*=Betchworth and Brockham, *g*=Guildford.

LIST OF FOSSILS FROM LOWER CHALK, SURREY.

	Zone of Am. varians.	Zone of H. subglobosus.	Belemnite Marl.
Pisces.			
Ptychodus decurrens, *Ag.*		o	
„ polygyrus, *Ag.*		o	
Cephalopoda.			
Ammonites [Haploceras] Austeni, *Sharpe*		? g	
„ [Acanthoceras] navicularis, *Mant.*	o		
„ [„] rotomagensis, *Brongn.*	b	b	
„ [Schloenbachia] varians, *Sow.*	o b		
„ [„] Coupei, *Brongn.*	o b		
sp. (large)		g	
Anisoceras armatus, *Sow.*	b		
Scaphites æqualis, *Sow.*	o		
Turrilites costatus, *Lam.*	b		
„ tuberculatus, *Bosc.*	b		
Actinocamax plenus, *Blainv.*			x
Nautilus deslongchampsianus, *d'Orb.*	o		
„ elegans, *Sow.*		g	
Gasteropoda.			
Pleurotomaria sp.	o		
Solarium granosum ? *d'Orb.*	o		
Trochus or Littorina	o		
Lamellibranchiata.			
Cardita tenuicosta, *Sow.*	o		
Exogyra haliotoidea ? *Sow.*		o	
Inoceramus latus, *d'Orb*, non *Mant.*	o b		
„ sp.		o g	
Lima elongata, *Sow.*	o		
„ globosa, *Sow.*	o	b	
Nucula sp.	o		
Pecten Beaveri, *Sow.*	?	o b	
Plicatula inflata, *Sow.*		o	
„ sigillina, *Woodw.*		b	
Brachiopoda.			
Rhynchonella Martini, *Mant.*	o		
„ sp.		b	
Terebratula biplicata, *Sow.*	o	b	
„ obesa, *Sow.*	o	o g	
„ semiglobosa, *Sow.*		o b	
Terebratulina gracilis (? triangularis *Eth.*)	o		
„ striata, *Wahl.*	o		
Crustacea.			
Enoploclytia sussexiensis, *Mant.*		b	
Pollicipes sp.	o	o	
Echinodermata.			
Discoidea cylindrica, *Lam.*		o	
Holaster subglobosus, *Leske*		b	
„ laevis, *de Luc*		o	

CHAPTER V.

THE LOWER CHALK IN HAMPSHIRE.

General Description.

The outcrop of the Lower Chalk, when it enters Hampshire a little west of Farnham, begins to widen out; the dip of the beds lessens in amount, and changes in direction from a northerly one to north-westerly and finally a westerly one. In consequence of these changes the tract occupied by the Lower Chalk passes southwards by Froyle, Alton, Farringdon, Newton-Valence, Froxfield, and East Meon. East Meon is situated on the southern anticlinal axis of the Wealden area, an axis which is prolonged westward through Winchester, and to the south of this anticline the beds, of course, dip southward. Consequently at East Meon the strike of the Lower Chalk changes its direction again and runs eastward below Ramsdean Down to Buriton, and thence into Sussex.

So far as we can judge, from the position of the Belemnite Marl on Stoner Hill north-west of Petersfield, with reference to the base line of the Chalk drawn by Mr. Hawkins, the total thickness of the Lower Chalk in Hants is about 200 feet. A boring made for the Local Board at Ashdell, Alton, in 1882, and published by Mr. Whitaker is given as follows: —

		Ft.	Depth.
Well dug in chalk		140	140
Lower chalk and grey chalk		68	208
Chalk–Marl	probably	50	258
Chloritic Marl	,,	10	268
Malm rock		80	348
Gault		150	498
Gault (? partly hard Lower Greensand)		42	540

As the railway cutting close by is in Melbourn Rock, the thickness ascribed to the Lower Chalk (258 feet) seems great. Possibly the Chalk ends at 208 feet, and the beds below down to 348 feet belong to the Malmstone.

The only person, prior to 1875, who paid any attention to the Lower Chalk in Hampshire was the late Mr. W. Curtis, of Alton, who collected many fossils from the quarries in the neighbourhood of Alton between 1850 and 1860. These fossils are preserved in the Museum at Alton. It is stated in the Geological Survey Memoir on Sheet 12 (old series, 1862), that Mr. Curtis had found the "Chalk-Marl" susceptible of division into three parts: by Chalk-Marl it is probable that the writer meant the whole of what is now called Lower Chalk, and the three parts are thus described: "The base of the series is composed of a loose, pale grey marl with beds and concretions of a harder substance, and in some parts it is quite of a blue colour. Above it a white marly chalk, resembling Upper Chalk, is overlain by a very hard dark green marl which is quarried at Wilsham." Wilsham is the name of a small hamlet half a mile east of Alton and just below the outcrop of the Melbourn Rock; there are old quarries there, and thus it seems most probable that the dark green marl seen by Mr. Curtis was the zone of *Actinocamax plenus*. If so, the succession which he describes is a perfectly correct one, and is true for the whole of Hampshire. Professor Barrois who visited Alton and the neighbourhood in 1875, formed the same idea of Mr. Curtis's observations, and added some notes of his own.*

THE MAIN OUTCROP.

Zone of Ammonites varians.

Chloritic Marl.—The existence of a phosphatic bed at the base of the Chalk in the north of Hampshire was first made known by Messrs. Paine and Way in 1848.† They describe it as a bed about 3 feet thick, consisting of a green marl more or less siliceous (*i.e.*, sands), and abounding in organised fossil remains. The fossils were not evenly dispersed throughout the stratum, "but often lie in most irregular heaps;" their principal constituent is phosphate of lime, and the marl itself, even when the fossils and nodules have been sifted out, often yields on analysis from 10 to 15 per cent. of phosphate of lime.

In their exploration of the bed they describe it as occurring on the north-west side of Farnham below the Castle, and running in a W.S.W. direction through Beaver's Hill and the central part of Dippen Hall Farm, and thence to Bentley. From Bentley "the phosphoric band, proceeding in a south-west direction, may be traced to Froyle, in which parish it crosses the Southampton road; it then continues with the same bearing till it crosses the River Wey below Alton, and is traceable, though occasionally much obscured by diluvial detritus, to Worldham. Here there is an immense longitudinal quarry about 15 feet in depth, from which at some remote period thousands of loads have been removed."

With respect to the phosphatic nodules themselves, they describe them as of three kinds. The first includes fossils of various sorts, fine specimens "of the siphonia pyriformis and of other alcyonites are profusely abundant," together with "quantities of large amorphous spongoid bodies, which possess a general uniformity of structure." They also found a peculiarity in this class of fossils, for not only do they differ greatly from each other in chemical composition, and especially with respect to the amount of phosphate of lime they contain, but they also vary in their own component parts, their outer part being richer in phosphate. A large specimen of one of these hard, solid spongoid bodies was divided into sections, which, on being analysed, gave the following results :—

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* Recherches sur le Terr. Crét. Sup., 1876, p. 44.

† See Journ. Roy. Agric. Soc., Vol. ix. p. 75, and Vol. xii. p. 544.

Exterior - -	32·27—phosphate of lime. 61·71—carbonate of lime.
Intermediate	13·87—phosphate of lime. 67·14—carbonate of lime.
Interior - -	10·26—phosphate of lime. 69·17—carbonate of lime.

proving, as he remarks, that the phosphoric acid was external in its origin.

" Another abundant supply of phosphate of lime is derived from shapeless lumps of various sizes. They are always of a light reddish-brown colour ; when first dug they are very soft, and never attain a greater hardness than that of soft white chalk. Their specific gravity is small compared with the other nodules. . . . These lumps are invariably rich " (in phosphate).

" But there is another description of organic remains which are found in still greater profusion. They consist of very dark brown lumps of every form and size, some are microscopically small, others attain the weight of three and four pounds : they are both heavy and hard." They remark that this substance must once have existed in a soft plastic state " since many of them are agglutinised to the surfaces of the syphoniæ, corals, shells, teeth, and wood which occur with them. "

They give analyses of several samples of these phosphates which will be reproduced in a later volume.

At the present time no phosphates are dug, and there are now few places where the bed can be seen, but twenty or thirty years ago a good section was exposed in a quarry recorded by Mr. Topley and stated to be half a mile north-west of Week Green (Wych House ?).

This quarry is about a mile south-east of Holybourne, and is now (1896) part of a small wood overgrown with trees and shrubs, but by clearing the south-east corner Mr. Hill obtained the following section :—

		ft.	in.
Chalk Marl.	Hardish white marly chalk, passing rapidly down to a very glauconitic marl—*Am.* [*Schloenbachia*] *Coupei* - - -	4	0
Chloritic Marl.	Firm, very glauconitic marl, with many brown phosphates and large calcareo-siliceous lumps, brownish-grey interiorly, but with a paler rind, as large as a double fist—*Avicula gryphæoides* and a large *Nautilus*	1	6
Upper Greensand.	Grey-brown silty or sandy marl into which the glauconitic material above is piped -	1	6
		7	0

Some three miles farther south a similar section, showing a decided increase in the thickness of the Chloritic Marl occurs at a quarry half a mile south of Barleywood Farm, and about a mile E.N.E of Farringdon.

		ft.	in.
Soil		1	0
Chalk Marl.	Chalk rubble	4	0
	Whitish-grey (very dry) marly chalk, with hard masses arranged in layers—*Am.* [*Schloen.*] *varians, Rhynch. grasiana, Ter. semiglobosa;* passing down to the next	2	6
Chloritic Marl.	Firm micaceous glauconitic sandy marl with brown phosphates and large calcareo-phosphatic lumps *Am.* [*Schloen.*] *varians, Avicula gryphæoides, Plicatula gurgitis* and a large *Nautilus*	3	6
Upper Greensand.	Soft grey silty and sandy marl into which the glauconitic material is piped	1	0
		12	0

The junction beds are also exposed at Water Lane a quarter of a mile due east of Truncheaunt's Farm, but the section is not very clear. The junction of the Chalk and Upper Greensand has not been observed again between this point and where a "greenway" meets a cross lane at right angles, 330 yards W.N.W. of Twentyways Farm, near Ramsdean, some 1½ mile due east of East Meon. Here the bright greensand of the Upper Greensand is capped by a bed of hard concretionary masses, containing *Am.* [*Schl.*] *varians* and another species, and above this a pale grey very glauconitic calcareous marl is seen to pass up to Chalk Marl. This exposure is partly in a hedge bank and partly in a shallow ditch, where running water has cleared the surface soil.

Fragments of concretionary masses full of *Am.* [*Schl.*] *varians* were seen in hedgerows and ploughed land between this point and Buriton on the line indicating the summit of the Upper Greensand on the maps of the Geological Survey.

Chalk Marl.—There is no quarry in Hampshire which exhibits any considerable section of the Chalk Marl.

About a mile north of Bentley in Lock's Grove plantation, Mr. C. E. Hawkins saw much jointed marly chalk, and in Black Acre copse, a quarter of a mile north-west of Bentley, rather sandy marly chalk was noticed, but there was no section.

Dr. Barrois (op. cit., p. 49) records that at Neatham, near Holybourne, he saw several metres of bluish-grey argillaceous marl crumbling down quickly on exposure to the air, but containing many small brachiopods, especially *Rhynchonella mantelliana* and *Terebratulina striata*.

A large quarry on the Weatham Hill, two miles north of Petersfield, shows beds which probably belong to the higher part of this zone. They are as follow:—

	ft.	in.
Soil	2	0
Greyish (wet) rather marly chalk	13	0
Greyish rather marly chalk, mottled with large patches of bluish-grey	8	0
Hard grey sandy chalk, *Terebratula biplicata*	2	0
Softer chalk, mottled with large patches of bluish-grey	6	0
Hard grey chalk, *Am.* [*Acanthoceras*] *rotomagensis*	1	0
Bluish-grey marly chalk, passing down to greyer chalk	4	0
Grey firm chalk slightly mottled with bluish-grey	4	0
Massive firm marly chalk mottled with large patches of bluish-grey	15	0
	55	0

In the quarry-like cuttings by the side of the road which leads from Petersfield to Portsmouth between War Down and Butser Hill, the upper part of this zone is just seen. The chalk is bluish-grey in colour and hard and soft layers alternate, small Brachiopods were common, and there were casts of Ammonites (*?Am.* [*Schl.*] *varians* and *Am.* [*Acanth.*] *Mantelli*).

Zone of Holaster subglobosus.

Progressing round the margin of the Weald from Surrey through Hampshire, the first good section noticed by Mr. Hill in the upper part of the Lower Chalk was in a quarry about a quarter of a mile south of Alton station. The basal 10 or 12 feet of this quarry is in grey chalk, which passes up to hard white chalk, of this some 35 feet is exposed, but it was in a broken-up, rubbly condition, and no detailed section was taken. Immediately above the main face shallow workings recently opened exposed 10 or 12 feet more hard white chalk, but nothing like the Belemnite Marls was seen; though the late Mr. W. Curtis seems to have seen these marls somewhere near Alton (see p. 57).

In a small disused roadside quarry about one-third of a mile S.S.E of Alton Station, and again in a quarry half a mile N.N.E. of Farringdon, a grey gritty chalk somewhat like Totternhoe Stone was exposed, in which *Pecten orbicularis*, *Kingena lima*, and *Rhynchonella grasiana* were common, but there were no *Ammonites*.

In a disused quarry half a mile west of Hawkley Church, near where some talus had been cleared away, a similar gritty chalk was exposed, and large blocks of it lay about the quarry floor. Mr. Hill found the same fossils with the addition of *Pecten elongatus* *Terebratulina striata* and *Trochus Buvignieri*; there were also impressions of an Ammonite.

This gritty bed appears to be about 60 to 65 feet below the Melbourn Rock. In the same quarry at the top of the talus slope about 6 feet of rather hard whitish chalk was exposed.

It is stated by Dr. Barrois that the junction of the zone of *Holaster subglobosus* with the overlying zone of *Inoceramus mytiloides* was visible in a quarry at Chewton, south of Alton, but whether this is the pit at Southfield Farm or at some other opening we are unable to say.

The outcrop of the marl was observed in 1897 in a bye road crossing Ridge Hanger to Stoner Hill two miles north-west of Petersfield just above the contour line of 600 feet.

At the lime works half a mile north of Langrish House, three miles west of Petersfield, about 25 feet of firm, whitish chalk is seen. Professor Barrois (op. cit., p. 36) notes this quarry, and records the following fossils:—*Turrilites costatus, Am.* [*Acanth.*] *rotomagensis, Baculites baculoides,* and *Inoc. striatus.* It would appear from his description and from the occurrence of these fossils that the quarry was then worked to a lower level than it is at the present time.

In the quarries which adjoin the main road from Petersfield to Portsmouth, as it passes between War Down and Butser Hill, about three miles from Petersfield, 50 or 60 feet of blocky white chalk is seen, and this, with the road cuttings, must expose nearly the whole of the upper part of the Lower Chalk; the Belemnite Marls are obscured, according to Mr. C. E. Hawkins, though the Melbourn Rock can be identified a little higher up the hill.

About 80 feet of the upper part of the Lower Chalk is seen at the large quarries at Buriton, but, like the section near Butser Hill, the Belemnite Marls are not quite exposed.

In all these quarries the chalk is unfossiliferous and uninteresting.

THE WINCHESTER INLIER.

The inlier of Lower Chalk at Winchester is a small area on the east side of the Itchen Valley, running from Bar End to Chilcombe. Mr. Ch. Griffith, of Winchester, has courteously supplied us with the following particulars and lists of fossils:—

"There is a large pit at Chilcombe, showing the upper beds of the Lower Chalk overlain by the Melbourn Rock and zone of *Rhynchonella Cuvieri.* The band of *Actinocamax plenus* presents two layers of grey marl with a bed of firm chalk between them. No fossils have been found in the marls, but in the central bed and in the chalk immediately below the lower marl there are—

Corax heterodon.
Ptychodus decurrens.
Actinocamax plenus.
Aporrhais sp. (? Mantelli).
Inoceramus sp.
Ostrea vesicularis.
Pecten Beaveri.
Enoploclytia sp.
Rhynchonella Cuvieri.
Discoidea minima.
Pseudodiadema sp.
Stephanophyllia sp.

"The zone of *Holaster subglobosus* is exposed for about 30 feet, and consists of firm, massive chalk, greyish when wet but drying white. The same chalk is also found in a pit recently opened at Bar End, where it has yielded the following fossils:—

Cimolichthys lewesiensis.
Corax falcatus.
Lamna appendiculata.
Scapanorhynchus raphiodon.
Oxyrhina Mantelli.
Protosphyræna ferox.
Ptychodus decurrens.
,, mammillaris.
, polygyrus.
Macropoma sp.
Terebratula semiglobosa.
Holaster trecensis.

"Another small pit about 10 feet above the last has yielded a specimen of *Actinocamax plenus.*

"A well sunk by the roadside between Bar End and Chilcombe reached lower beds consisting of blue-grey chalk which yielded *Rhynchonella mantelliana, Plicatula pectinoides, Lima globosa,* and other fossils. More recently a well has been sunk at a cottage close to the quarry at Chilcombe, going to a depth of 170 feet, and thus, without doubt, reaching the zone of *Am. varians.*"

THE KINGSCLERE INLIER.

The Lower Chalk forms a band of varying width round the Selbornian outcrop of this inlier, and a good section of the central and upper beds is exposed in the railway cutting south of Burghclere. I am informed by Mr. F. J. Bennett that this shows marly chalk at the northern end, above which comes a bed of grey shelly chalk much resembling the Totternhoe Stone, and above this some thickness of greyish blocky chalk. The following fossils were obtained from the beds by Mr. Rhodes :—

	Chalk Marl.	Grey shelly chalk.	Blocky chalk.
Ptychodus decurrens, *Ag.*	—	—	x
Beryx sp.	—	—	x
Ammonites [Acanth.] rotomagensis, *Brongn.*	x	—	—
,, [Schloenb.] varians, *Sow.*	x	—	—
,, [,,] Coupei, *Brongn.*	x	—	—
,, sp.	—	—	x
Inoceramus mytiloides ? *Mant*	x	—	—
,, sp.	—	x	x
Lima globosa, *Sow.*	x	—	x
Ostrea vesicularis, *Lam.*	—	—	x
Pecten orbicularis, *Sow.*	—	x	—
Plicatula inflata, *Sow.*	—	x	—
Rhynchonella grasiana, *d'Orb.*	x	—	—
,, mantelliana, *Sow.*	—	x	—
Terebratula semiglobosa, *Sow.*	—	x	x
Enoploclytia sp.	—	—	x
Serpula umbonata, *Sow.*	—	x	x
Cidaris Bowerbanki, *Forbes*	—	—	x
Discoidea cylindrica, *Lam.*	—	—	x
Holaster sp.	—	—	x
Micrabacia coronula, *Goldf.*	—	x	—

CHAPTER VI.

THE LOWER CHALK IN SUSSEX.

1. West Sussex.

General Description.

Sussex being a long county, and including nearly the whole of the South Down range, it will be convenient to divide our description of the Lower Chalk of Sussex into two portions. We shall regard the western part as extending from the boundary of Hampshire to the valley of the Adur, a distance of about 26 miles.

In this part of Sussex the features presented by the basset surface of the Lower Chalk resemble those of the same surface in Surrey, and differ from those of the Hampshire outcrop. In other words, the outcrops form a steep slope, except near the base, where the Chalk Marl generally runs out in a gentle slope or plain to meet the inward or southward slope of the Greensand terrace.

With respect to zonal and lithological composition the Lower Chalk of this region may be regarded as a continuation of that of Hampshire. There is a similar bed of Chloritic Marl at the base, overlain by a certain thickness of soft grey crumbling marl which passes up into bluish-grey marly chalk. The upper beds consist of white blocky chalk crowned by a bed or beds of firm, greenish-grey marl (the zone of *Actinocamax plenus*).

In regard to thickness, also, there seems to be little change. Mr. Reid informs us that he considers there is at least 180 feet of chalk between the basement-bed and the Belemnite marl at the top.

Although the chalk of Sussex has yielded many fine fossils, and large collections were formed by Dr. Mantell and Mr. Dixon, yet these collections were made before any accurate division of the Chalk was established. Fossils referred by them to the Chalk Marl may safely be included as Lower Chalk fossils, and probably most of them will have come from the zone of *Ammonites varians*, but the Lower Chalk of Mantell and Dixon was simply the more solid chalk without flints, and consequently included part of the Turonian, or Middle Chalk.

Since that time few geologists have examined the Lower Chalk of Sussex, and the western part of the county has been quite neglected. We are not aware that anyone has described the zonal succession at any locality, and we ourselves have not had time to make special researches in this area.

The whole Chalk area of Sussex was, however, re-surveyed during the years 1889-1891 by Mr. C. Reid, who drew the lines for the Chalk Rock and Melbourn Rock, but was instructed not to take more than brief notes of the principal exposures in the Chalk. These notes have been placed at our disposal. Mr. R. M. Brydone has kindly communicated a note on the quarries near Duncton, and Mr. Hill has visited the quarries near Bury and Amberley in making a traverse down the valley of the Arun. From these sources the following account has been drawn up, and will serve to indicate the exposures that would probably repay attention.

STRATIGRAPHICAL DETAILS.

There is a quarry near Elstead, on the north-west side of Beacon Hill, which exposes the grey marly chalk of the *Ammonites varians* zone, and from this Mr. Rhodes obtained some fossils (see p. 67).

In road cuttings and old quarries south of Heyshott Mr. Reid saw the following succession:—

	Melbourn Rock.
Lower Chalk.	Belemnite Marl.
	Coarse-grained chalk.
	Massive grey chalk.
	Chalk Marl.
	Hard sandy glauconitic marl.
	Greensand.

The "coarse-grained chalk" was exposed in the roadway, but not in the quarries. He estimates the thickness here at 180 to 200 feet.

There are two quarries in the Lower Chalk south of Duncton Church. The lower of these is now disused and talused, but Mr. Brydone states that a good section of the Chalk Marl was formerly exposed here, and that he obtained many fossils from it. Writing of them he says:—

"The greater number of the fossils came from the lowest band in the pit, a bed of dark bluish-grey marl about 4 feet thick, soft when wet, but drying to a hard marl, and having a notably conchoidal fracture. *Brachiopoda*, *Serpula*, and *Onchotrochus* were especially abundant in this marl; other fossils were less common. Above this is about 10 feet of lighter grey chalk with few fossils, succeeded by a bed of very hard chalk mottled in light and dark grey, and containing many *Cephalopoda*."

The floor of the pit from which these fossils came is probably about 50 feet above the base of the Chalk.

A little to the eastward, and about 100 feet higher up the slope, is another quarry and limekiln where about 60 feet of chalk are shown, belonging to the zone of *Holaster subglobosus*. The species found by Mr. Brydone are given below, but he says that fossils, except *Ostreidæ*, were scarce.

Again, in the lane leading up West Burton Hill, Mr. W. Hill saw beds of greyish-white chalk alternating with beds of marly chalk; *Am.* [*Schloenbachia*] *varians* and *Am.* [*Acanthoceras*] *Mantelli* occurred frequently at a spot considerably more than 100 feet above the base of the Chalk. Ascending the lane these beds give way to more massive lighter coloured chalk, and the top of the Lower Chalk is reached a little to the north of the tumuli, but there is no clear section, and the Belemnite Marls were not seen.

Mr. Hill found the upper part of the Lower Chalk exposed in the quarry, half a mile south-west of Bury, but in the face now being worked a slip seems to have occurred, the beds being distorted and broken. The Belemnite Marl is exposed in the south-east corner.

Mr. Reid saw the lower part of the Chalk Marl in the railway cutting between Amberley and Amberley Station, and he describes it as consisting of " sandy marl and hard bluish marl containing small grains of glauconite and some flakes of mica." He also remarks that " between Sullington Hill and Bury a grey sandy or siliceous chalk appears about 140 feet below the Melbourn Rock, and almost immediately below the Grey Chalk. This material seems to replace part of the Chalk Marl and not to belong to the Greensand."

The following note is by Mr. Hill :—Mr. Pepper's quarry, about a quarter of a mile north of Amberley Station, is about 80 feet deep ; 60 feet of this is in massive smooth white chalk, passing down into greyer chalk, the lowest 10 or 12 feet being in courses divided by marly bands. In the floor of the quarry a narrow working disclosed about 20 feet more of grey chalk and grey marl in alternating courses. No fossils were seen, nor did the quarrymen possess any.

The following is a list of such fossils as have yet been obtained from definite zonal horizons in western Sussex. Those from Elstead were obtained by Mr. Rhodes, those from Duncton by Mr. Brydone.

FOSSILS FROM THE LOWER CHALK OF WESTERN SUSSEX.

	Am. varians Zone.			Hol. subglobosus Zone. Duncton.
	Elstead.	Duncton.	Amberley.	
Fish.				
Beryx sp. - - - - -	–	–	x	
Calamopleurus anglicus, *Dixon* -	–	–	x	
Cimolichthys lewesiensis, *Leidy* -	–	–		–
Enchodus lewesiensis, *Mant.* -	–	x		–
Edaphodon Agassizi, *Buckl.* -	–	–	x	–
Lamna appendiculata, *Ag.* -	–	x	x	–
Microdon occipitalis, *Ag.* - -	–	–	x	
Notidanus microdon, *Ag.* -	–	–	x	–
Tetrapterus minor, *Ag.* - -	–	–	x	–
Mollusca.				
Am. [Acanth.] navicularis, *Mant.*	–	x		–
,, [,,] rotomagensis, *Brongn.*	–	x		–
,, [Schloenb.] varians, *Sow.* -	x	x		–
,, ,, Coupei, *Brongn.*	–	x		–
,, sp. - - - -	–	–		x

FOSSILS FROM THE LOWER CHALK OF WESTERN SUSSEX.—*contd.*

	Am. varians Zone			Hol. subglobosus Zone.
	Elstead.	Duncton.	Amberley.	Duncton.
Baculites baculoides, *d'Orb.* -	x	x	–	–
Scaphites æqualis, *Sow.* - -	–	x	–	–
Turrilites costatus, *Lam.* - -	x	–	–	–
„ tuberculatus, *Bosc.* -	–	x	–	–
Nautilus elegans, *Sow.* - -	?	x	–	–
Cerithium (? ornatissimum) -	–	x	–	x
Natica sp. - - - - -	–	x	–	–
Pleurotomaria sp. - - -	–	x	–	–
Solarium sp. - - - - -	–	x	–	–
Exogyra haliotoidea, *Sow.* - -	–	–	–	x
Inoceramus striatus, *Sow.* -	–	x	–	–
„ sp. - - - -	–	–	–	x
Lima elongata, *Sow.* - - -	–	x	–	–
„ globosa, *Sow.* - - -	–	x	–	x
Ostrea acutirostris, *Nilss.* - -	–	x	–	–
„ vesicularis, *Lam.* - -	x	x	–	–
Pecten Beaveri, *Sow.* - -	–	x		–
„ orbicularis, *Sow.* - -	–	x	–	x
„ (Neithea) 5-costata, *Sow.*	–	x	–	x
Plicatula inflata, *Sow.* - -	x	x	–	x
Brachiopoda.				
Kingena lima, *Defr.* - - -	x	–	–	–
Magas Geinitzi, *Schloenb.* - -	–	x	–	–
Rhynchonella grasiana, *d'Orb.* -	–	x		–
„ mantelliana, *Sow.*	x	x	–	–
„ Martini, *Mant.* -	x	x	–	–
„ dimidiata, *Sow.* -	x	–	–	–
Terebratula biplicata, *Sow.* - -	x	–	–	–
„ squamosa (?) *Mant.*	–	x	–	–
Terebratulina striata, *Wahl.* -	x	x	–	x
Arthropoda.				
Pollicipes sp. - -	–	x	–	–
Serpula ampullacea, *Sow.* - -	–	x	–	x
„ annulata, ? *Reuss* - -	–	x	–	–
„ macropus, *Sow.* - -	–	x	–	x
„ umbonata, *Sow.* - -	x	x	–	–
„ plexus, *Sow.* - -	–	x	–	–
„ „ var. gordialis *Roem.*	–	x	–	–
Echinodermata.				
Calliderma mosaicum, *Forbes* -			x	
„ Smithiæ, *Forbes* - -	–	–		
Cidaris (spines) - - - -	x	–	–	–
Echinocyphus difficilis, *Ag.* -	–	–	–	x
Holaster sp. - - - -	–	–	–	x
Pentacrinus sp. - - - -	–	–	–	x
Cœlenterata.				
Onchotrochus serpentinus, *Dunc.*	–	x	–	–
Plocoscyphia labrosa *Smith* -	–	–	x	

2. Eastern Sussex.

Having defined Western Sussex as that part which lies between Hampshire and the valley of the Adur, we have now to follow the Lower Chalk through the remaining part, which lies between the Adur and the coast near Eastbourne, a distance of about 30 miles along the outcrop.

Eastern Sussex contains many classical localities for Lower Chalk fossils, but no one has collected from them since the establishment of zones and of a definite Middle Chalk (except along the coast); consequently we do not yet know the exact age of many of Mantell's types. It is to be hoped that some geologist will arise in Sussex who will follow in Mantell's footsteps, and collect carefully from the successive zones, so as to ascertain the range of all the fossils which have been figured by Mantell and Dixon.

The general succession of the beds in Eastern Sussex is similar to that in the western part of the country. There is a certain thickness of soft grey chalk-marl above the basement-bed, but its upper limit does not coincide with that of the *Am. varians* zone, for that species is found above it. The zone of *Holaster subglobosus* consists of the usual blocky chalk, grey below but lighter above, and nearly white below the Belemnite Marls, which in the coast section have the unusual thickness of about 15 feet.

A.—Inland Exposures.

The following information is taken from notes by Mr. Reid:—

Between the river Adur and the Devil's Dyke the outcrop of the Lower Chalk is very narrow, and most of the roads down the steep slopes of the escarpment expose sections. Most of these cuttings show Chalk Marl overlain by grey chalk.

Clayton tunnel on the London and Brighton Railway traverses the greater part of the Lower Chalk, for Chalk Marl is seen at its northern end, and the cutting at the south end shows the Belemnite Marl overlain by Melbourn Rock.

Massive greyish chalk, belonging to the middle part of the Lower Chalk, is seen in the quarry of the Clayton Limeworks.

The highest part of the Lower Chalk is exposed in a quarry near Plumpton, five miles west of Lewes. The following note of the section was taken by Mr. W. Hill in 1897:—

			ft.	in.
Middle Chalk.		Hard rough nodular much-broken chalk—*Inoc. mytiloides* and *Rhynch. Cuvieri*	25	0
		Smooth, hard white chalk	1	9
Lower Chalk.	Belemnite Marls.	Marly chalk	0	8
		Hard whitish-grey marly chalk	1	0
		A strongly-marked band of dark grey marl	0	2
		Firm greyish marly chalk	0	6
		Bed of dark grey marl, but not so strongly marked as that above	0	3
		Firm grey marly chalk with conchoidal fracture, passing gradually to firm massive whitish chalk	4	6
		Firm massive whitish chalk seen for	25	0

It will be seen that the Belemnite beds are here divisible into six layers of marl and marly chalk and that the lowest bed passes gradually into the whiter part of the Lower Chalk. As bracketed, the thickness of the Belemnite beds amounts to about 7 feet, but the grey marly portion is not more than 6 feet.

The best inland exposures of the Lower Chalk in Sussex are those of the quarries near Lewes, and considering how many of Dr. Mantell's fossils were obtained from the Lower and Middle Chalk of Lewes and Glynde, it is rather surprising that no description of these sections has ever been published.

With the view of ascertaining what zones were represented near Lewes, Mr. Rhodes was sent down to collect from the various quarries and especially to note the range of *Am.* [*Schloenb.*] *varians* in the Lower Chalk. The following account is drawn up chiefly from the notes supplied by Mr. Rhodes :—

The Chalk Marl with *Am.* [*Sch.*] *varians* is exposed in the railway cutting east of Offham, and also on the main line by Hamsey Place Farm.

Lewes itself lies in a syncline, and the Lower Chalk comes to the surface again on the southern side of the hills at Kingston, Southerham, and Glynde. A large pit to the east of Southerham Farm, known as "Southerham Grey Pit," shows about 70 feet of the Lower Chalk, with a dip to the W.N.W. The lower 20 feet consist of alternating beds of hard grey chalk and soft marly chalk, and contain *Am.* [*Schloenb.*] *varians* and other fossils; they are succeeded by beds of grey chalk with partings of marl, containing *Holaster subglobosus*, *Am.* [*Acanth.*] *Mantelli*, and *Am.* [*Acanth.*] *Sussexiensis*.

Another large quarry adjoins Glynde Station, and shows lower beds, for it is about 80 feet deep, and the lower 60 are in the alternating beds of hard and soft chalk with *Am.* [*Schloenb.*] *varians*, *Inoceramus latus*, *Terebratula biplicata*, etc., while the upper 20 feet is more thickly bedded with marly partings, like that at Southerham.

In Mantell's time (1816 to 1836) there were exposures of the Chalk Marl at Hamsey, Stoneham, Middleham, and Ringmer, which are all villages or farmsteads to the north and north-east of Lewes. From these places Mantell obtained most of his Chalk Marl fossils, but no pits are now open at any of them.

The following is a list of fossils from the Lower Chalk of the neighbourhood of Lewes, compiled from the following sources (1) Mantell's own list of "Chalk Marl Fossils" in the Trans. Geol. Soc., Ser. 2, Vol. III., p. 208, (2) from Dixon's "Geology of Sussex" (Second edition), (3) the catalogue of Mr. Willett's collection in the Brighton Museum, (4) a collection made by Mr. Rhodes for the Geological Survey. in 1896.

In Mantell's list of "White Chalk" fossils there are a few which evidently came from the upper and whiter part of the Lower Chalk, such as *Am.* [*Haploceras*] *catinus* from Southerham, a species which Sharpe states to be from the "Grey Chalk." We have therefore inserted this and others from Mantell's list under the zone of *Hol. subglobosus,* and have distinguished them by s. (Mant.) if from Southerham, or by the locality in full.

The letters in the list stand for the localities, thus—

h=Hamsey.
m=Middleham.
r=Ringmer.
c=Clayton
l=Cuttings north of Lewes.
n=Newtimber.
s=Southerham.
g=Glynde.

Those from the first three are solely on Dr. Mantell's authority, and we have entered them all as coming from the zone of *Ammonites varians,* as from the position of the places, and from his calling the rock "Chalk Marl," it seems probable that they came from that zone.

List of Fossils from the Lower Chalk near Lewes.

	Zone of Am. varians.	Zone of Hol. subglobosus.
Reptilia.		
Chelonian bones	c	
Coniasaurus crassidens, *Owen*	c	
Plesiosaurus sp.		s
Pterodactylus (Ornithocheirus) Cuvieri, *Bowerb.*	n	
Pisces.		
Acrodus Illingsworthi, *Ag.*	s	
Beryx microcephalus, *Ag.* (Ctenothrissa)	g s	
,, radians, *Ag.* (Ctenothrissa)	g s	
,, superbus, *Dixon* (Hoplopteryx)	g s	
Berycopsis elegans, *Dixon*	c	
Cestracion canaliculatus, *Eg.*	c s	
Cimolichthys lewesiensis, *Mant.*	g	
Corax falcatus, *Ag.*	g	
Cœlorhynchus cretaceus, *Dixon*	c	
Dercetis elongatus, *Ag.*	g	
Edaphodon Mantelli, *Buckl.*	c g	
Enchodus lewesiensis, *Mant.*	c	
Lamna appendiculata, *Ag.*	g	
Notidanus microdon, *Ag.*	g	
Oxyrhina angustidens, *Reuss*	g	
,, Mantelli, *Ag.*	g	
Pachyrhizodus Gardneri, *Mason*	g	
Portheus Mantelli, *Newton*	g	
Plethodus expansus, *Dixon*	c g n	
,, oblongus, *Dixon*	c	
Prionolepis angustus, *Eg.*	c	
Protosphyræna ferox, *Leidy*	c g	
Ptychodus decurrens, *Ag.*	g	
,, mammillaris, *Ag.*	g	
Scapanorhynchus sp.	g	
Tomognathus mordax, *Dixon*	s	

List of Fossils from the Lower Chalk near Lewes.—*contd.*

	Zone of Am. varians.	Zone of Hol. subglobosus.
Mollusca.		
Ammonites [Haploceras] Austeni, *Sharpe*	c s g	
,, [,,] catinus, *Mant.*		s. (Mant.)
,, [,,] cinctus, *Mant.*	m	
,, [Placenticeras] complanatus, *Mant.*	h	
,, [Hoplites] falcatus, *Mant.*	c h m	
,, [,,] curvatus, *Mant.*	h	
,, [Schloenbachia] goupilianus, *d'Orb.*	h	
,, [Acanthoceras] Mantelli, *Sow.*	m s	s g
[,,] navicularis, *Mant.*	s g	s
,, [,,] rotomagensis, *Brong.*	h l g	g
,, [,,] sussexiensis, *Mant.*	h	s
,, [Schloenbachia] varians *Sow.*	c h m l s g	
,, [Prionotropis] Woolgari ? *Sharpe*		
Actinocamax lanceolatus, *Sow.* non *Schloth.*	n	Steyning
Anisoceras armatus, *Sow.*	h	
Baculites baculoides, *Mant.* (=obliquatus *Sow.*)	h g	s g
Crioceras ? ellipticus, *Mant.*	r	
Hamites attenuatus ?, *Sow.*	c h	
,, alternatus, *Mant.*	r	
,, plicatilis	h	
Nautilus deslongchampsianus, *d'Orb.*	c h	
,, elegans, *Sow.*	c m	
,, expansus, *Sow.*	c m s g	
,, fleuriausianus, *d'Orb.*	n	
Scaphites æqualis, *Sow.*	c h l s g	
,, ,, var. obliquus, *Sow.*	c h	
Turrilites costatus, *Lam.*	h l	
,, gravesianus, *d'Orb.*	m	
,, Mantelli, *Sharpe*	c	
,, scheuchzerianus, *Bosc.*	h	
,, tuberculatus, *Bosc.*	c m	
Aporrhais Parkinsoni, *Mant.*	c h	
Avellana cassis ? *d'Orb.*	c r	
Buccinum or Columbellina (?)	h	
Natica sp.	h	
Cassidaria incerta (Dolium nodosum,) *Sow.*	n	Clayton
Xenophora sp.	h	
Pleurotomaria perspectiva, *Mant.*	c h g	
,, ,, var. linearis, *Mant.*	c h	
Scalaria compacta, *Sow.*	c	
Solarium catenatum, *Sow.*	g	
,, dentatum, *d'Orb.*		
,, granulatum, *Mant.*		s. (Mant.)
,, ornatum, *Sow.*		
Trochus	g	
Voluta ambigua (=semiplicata, *Gein.*)	h	
Avicula sp.	c	
Arca sp.	c r	
Cardita sp.	m	
Exogyra haliotoidea, *Sow.*	c	

List of Fossils from the Lower Chalk near Lewes.—*contd.*

	Zone of Am. varians.	Zone of Hol. subglobosus.
Mollusca.—Contd.		
Inoceramus Cripsi, *Mant.*	h	
„ latus, *d'Orb.* (non *Mant.*)	l s g	
„ tenuis, *Mant.*	h	
„ sp.		g
Lima aspera, *Mant.*	h	
„ elongata, *Sow.*	h	
„ globosa, *Sow.*	g	
Ostrea frons, *Park.*	c n	
„ vesicularis, *Lam.*		s
Pecten Beaveri, *Sow.*	c h g	s g
„ orbicularis, *Sow.*	c h l	
„ sp.	s	
„ (Neithea) 5-costatus, *Sow.*	c h	
„ „ triplicatus, *Mant.*	h	
Pholadomya decussata, *Phil.*	h m g	
Pinna decussata, *Goldf.*	s	
Plicatula inflata, *Sow.*	h g	s
Septifer lineatus, *Sow.* (=Modiola)	c	
Teredo amphisbæna, *Goldf.*	c	s
Unicardium ringmeriense, *Mant.*	m r	
Brachiopoda.		
Kingena lima, *Defr.*	l	
Rhynchonella grasiana, *d'Orb.*	l g	
„ mantelliana, *Sow.*	h	
„ Martini, *Mant.*	l	
„ rostrata, *Sow.* (uncertain sp.)	h	
Terebratula biplicata, *Sow.*	l s g	
„ semiglobosa, *Sow.*	h	s
„ squamosa, *Mant.*	h	
Annelida.		
Terebratulina striata, *Wahl.*	h s g	
Ditrupa difformis, *Sow.*	c	
Serpula annulata, *Sow.*	c	
„ plexus, *Sow.*	h	
„ umbonata, *Sow.*	h g	
„ „ var. Sowerbyi, *Phil.*	h	
Echinodermata.		
Calliderma Smithiæ, *Forbes*		
Cidaris Bowerbanki, *Forbes*	h n	
Cidaris Dixoni, *Cott.*	c	
Discoidea cylindrica, *Lam.* (Conulus in Mant.)	h	s
Holaster subglobosus, *Leske*	m	s
Peltastes clathratus, *Ag.*	g	
Pseudodiadema sp. (*Echinus saxatilis* ? *Mant.*)	h	
Crustacea.		
Enoploclytia Sussexiensis, *Mant.*	c g	s. (Mant.)
Coelenterata.		
Diblasus grevensis, *Lonsd.*	c	
Craticularia Fittoni, *Mant.*	h	

The following notes are furnished by Mr. C. Reid:—

Marly chalk is seen near Alciston, and in the escarpment south-west of that place there is an exposure of massive whitish chalk surmounted by the Belemnite Marl. At Wilmington the central part of the Lower Chalk appears to change its character, and to become a massive firm grey chalk, which forms a distinct feature along the escarpment, sometimes more conspicuous than that of the Melbourn Rock above. This facies continues eastward to Eastbourne.

Close to Folkington Church there is a pit in this massive grey chalk, and 300 yards to the north-west pink chalk is seen in the road. About 50 feet of the same massive chalk is well shown in the Ocklynge Chalk Pits, and Chalk Marl can be seen in the road below.

The Belemnite Marl is seen in the chalk pits at Ash, and also near Willingdon, near Southfields above the Grove, below Butts Down, and in the chalk pits above Jas Combe. As the base of the Chalk is also exposed near Willingdon, the difference between the heights of these exposures, as shown on the six-inch maps, gives about 200 feet as the approximate thickness of the Lower Chalk.

This estimate of the thickness of the Lower Chalk is confirmed by two borings made at the Star Brewery in Old Eastbourne, the site being about 50 yards from the church, and not far below the horizon of the Belemnite Marl. The older boring was made by Mr. R. B. Paten, of St. Albans, and is said to have traversed 202 feet of Chalk and Chalk Marl. A second boring was made in 1896, and we are indebted to the Rev. W. R. Andrews, for the following particulars obtained on the spot:—

	ft.
Chalk - - - - - - - - -	200
Greensand and rock - - - - - -	47
Gault clays - - - - - - - -	261
Greensand at - - - - - - -	508

B.—The Coast Section.

We now come to the coast section, where a good and clear exposure of the Lower Chalk might be expected. This, however, is unfortunately not the case, for the cliffs between Eastbourne and Beachy Head are broken by landslips, and show also signs of much squeezing and faulting, so that it is impossible to take a continuous section.

Before the sea wall was built below the Wish Tower there was a good section of the lowest beds, and the following account of it has been communicated by the late Rev. H. E. Maddock, who lived for some years at Eastbourne, and collected largely from the Lower Chalk:—

		ft
Chalk with green coated phosphatic nodules (Cast Bed) -		6 to 8
Chalk Marl with *Am.* [*Schloenbachia*] *varians* and "*Brachiclites*" at the base - - -	about	30
Chloritic Marl with phosphate nodules -	about	4½

A part of this succession can be seen on the scar west of the Wish Tower. The Chloritic Marl is a greenish glauconitic chalk, containing many brown phosphatic nodules, which are especially numerous near its base, where the rock is very green and sandy; the upper part is grey and less sandy, though full of green grains. It contains many fossils (see list on p. 76), and *Stauronema Carteri* is not rare.

The overlying Chalk Marl is soft, grey mottled with darker grey, and its lower part contains many of the Sponges which were formerly called *Brachiolites*, but are now known as *Plocoscyphia*. Above this soft marl, which may be 30 feet thick, there is a layer of compact grey shelly chalk, containing scattered green-coated phosphatic nodules, then light grey chalk with large patches of bluish-grey succeeded by another bed of shelly chalk with green-coated nodules. The nodule beds are each about a foot thick, and there is about 6 feet of chalk between.

These two nodule beds with firm grey chalk between them are seen again below Beachy Head, but are not well exposed in the cliff, for where they occur there are several faults. Mr. Hill, however, found the chalk above them to be a firm, compact light grey chalk in thick beds about 18 feet thick, and containing *Am. varians*. Above this 50 feet can be measured of light grey chalk, with streaks and patches of bluish-grey, in thick beds, which the wash of the sea works out into ridges. These beds contain *Am.* [*Acanthoceras*] *Mantelli*, *Am.* [*Acanth.*] *rotomagensis*, *Holaster subglobosus*, and other fossils (see list, p. 76). Hereabouts, however, some chalk must be cut out by slips and faults, for below the Belemnite Marls there is only 20 feet of firm greyish-white chalk. Probably a thickness of 50 feet is wanting.

The Belemnite marls are unusually thick near Eastbourne; they are well exposed both in Holywell Bay and below Beachy Head. In the cliffs of the bay the marls are about 15 feet thick, and consist of several beds, which vary in thickness, colour, and character within short distances. On the eastern side they comprise an upper and lower band of bluish-grey marl, with a central course of lighter grey marl, which splits into large angular fragments.

Near the water-course of the Pumping Station Mr. Hill took the following measurements:—

		ft.	in.
	Melbourn Rock—White nodular rocky chalk	10	0
Belemnite Marls.	Smooth grey marly chalk	1	3
	Firm grey marl divided into thin bed by seams of shaly marl	2	6
	Soft dark bluish-grey marl, passing laterally into grey marl from 8″ to	0	6
	Massive grey marl, with varying fracture, sometimes angular, sometimes conchoidal	7	6
	Bluish-grey marl	3	6
	Firm white chalk passing up into the above.		

Farther west the band is in two beds only, the upper a firm grey marl breaking into square blocks (8 feet), the lower a bluish-grey marl (7 feet).

Where the marls come down to the beach under Beachy Head they have thickened to more than 20 feet; this section is shown in Fig. 27, and the band consists of the following beds:—

	Feet.
Grey marl, weathering into rectangular slabs - - - - -	8
Massive grey marl, splitting conchoidally - - - - - -	3
Dark grey marl, breaking into small rectangular fragments	12

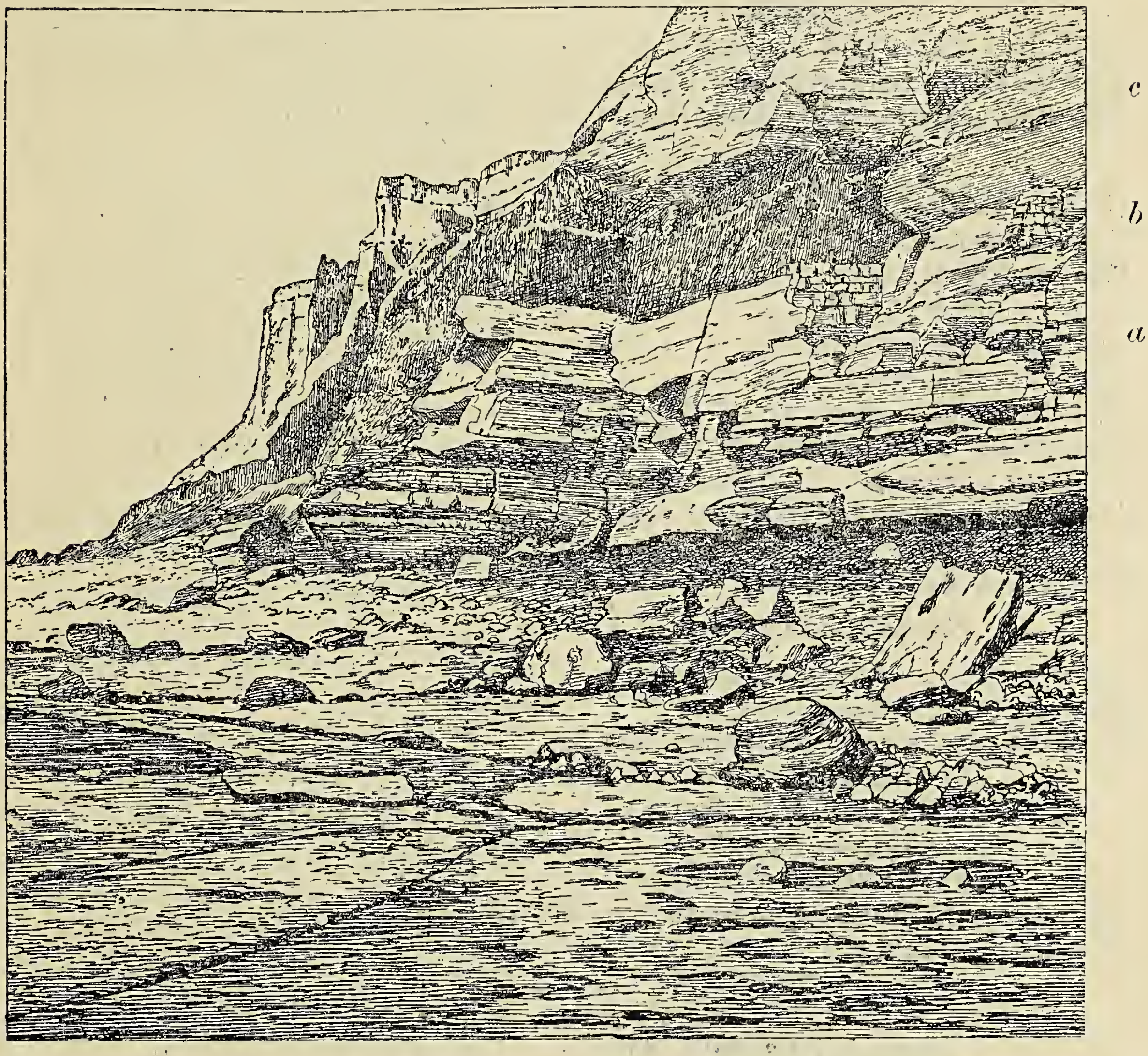

FIG 27.—View of the junction of the Lower and Middle Chalk below Beachy Head. Drawn from a photograph by the Rev. W. R. Andrews.

a. Lower Chalk. *b.* Belemnite Marls. *c.* Middle Chalk.

The following list of fossils from the Lower Chalk near Eastbourne is based upon collections made by the Rev. H. E. Maddock during his residence at that place, and on the examination of a collection from the Chloritic Marl made by Mr. H. G. Fordham, of Odsey, Herts. Nearly all the species were identified by me, but most of the Sponges were seen and named by Dr. Hinde.

List of Fossils from the Lower Chalk of Eastbourne.

The columns numbered 1 to 5 represent the divisions adopted by Mr. Maddock, and from which he collected separately. No. 1 is the Chloritic Marl; No. 2 is the lower 30 feet of the Chalk Marl; No. 3 is a bed in which he found many fossils, and which may be the equivalent of the cast bed of Folkestone; No. 4 includes all the chalk between Bed 3 and the Belemnite Marl; in other words, it includes the upper part of the *Am. varians* zone and all the chalk of the *Hol. subglobosus* zone. No. 5 is the Belemnite Marl.

——	Bed 1.	Bed 2.	Bed 3.	Bed 4.	Bed 5.
Reptilia.					
Chelonian plates and bones	–	x	–	–	–
Ichthyosaurus campylodon, *Carter*	x	x	–	–	–
Polyptychodon interruptus, *Owen*	x	x	–	–	–
Pisces.					
Beryx radians, *Ag.* (Ctenothrissa)	–	–	–	x	–
Corax heterodon, *Reuss* (=falcatus, *Ag.*)	–	–	–	x	x
Edaphodon Mantelli, *Buckland*	x	x	–	–	–
Macropoma Mantelli, *Ag.*	–	–	–	x	–
Lamna appendiculata, *Ag.*	x	x	–	x	x
Notidanus microdon, *Ag.*	x	–	–	x	–
Oxyrhina crassidens, *Ag.* (? Mantelli)	x	x	–	x	–
Ptychodus mammillaris, *Ag.*	–	x	–	x	x
Protosphyræna ferox, *Leidy*	–	x	–	–	–
Scapanorhynchus raphiodon ? *Ag.*	x	–	–	–	–
,, subulata, *Ag.*	–	x	–	x	–
Scales and Vertebræ	x	x	–	x	x
Cephalopoda.					
Actinocamax plenus, *Blainv.*	–	–	–	–	x
Belemnites ultimus, *d'Orb.*	x	–	–	–	–
Nautilus deslongchampsianus, *d'Orb.*	–	x	–	–	–
,, elegans, *Sow.*	–	x	–	–	–
,, expansus ? *Sow.* (large)	–	–	–	–	x
,, largilliertianus, *d'Orb.*	x	–	–	–	–
,, sublævigatus, *d'Orb.*	x	–	–	–	–
Ammonites [Acanth.] cenomanensis, *d'Arch.*	–	x	–	–	–
,, [Haploc.] cinctus, *Mant.*	–	–	–	–	x
,, [,,] lewesiensis, ? *Mant.*	–	–	–	x	–
,, [Hoplites] falcatus, *Mant.*	–	x	–	x	–
,, [Acanth.] Mantelli, *Sow.*	x	x	–	b	–
,, [,,] navicularis, *Mant.*	–	x	–	–	–
,, [,,] rotomagensis, *Brongn.*	b	x	x	–	–
,, [Schloenb.] varians, *Sow.*	x	x	–	?	–
,, [,,] Coupei, *Brongn.*	x	x	–	–	–
Anisoceras armatus, *Sow.*	–	x	x	–	–
,, sp.	x	–	–	–	–
Baculites baculoides, *Mant.*	x	x	x	x	–
Hamites simplex, *d'Orb.*	b	–	x	–	–
Scaphites æqualis, *Sow.*	x	x	x	–	–
Turrilites Bergeri, *Brongn.*	x	–	–	–	–
,, costatus, *Lam.*	–	–	x	x	–
,, gravesianus, *d'Orb.*	–	–	x	–	–
,, Mantelli, *Sharpe*	–	x	–	–	–
,, Morrisi, *Sharpe*	x	–	–	–	–
,, scheuchzerianus, *Bosc.*	–	x	x	x	–
,, tuberculatus, *Bosc.*	x	x	x	x	–
,, Wiesti ? *Sharpe*	–	–	–	x	–

List of Fossils from the Lower Chalk, Eastbourne.—*contd.*

——	Bed 1.	Bed 2.	Bed 3.	Bed 4.	Bed 5.
Gasteropoda.					
Aporrhais (Ornithopus) oligochila, *Gard.*	–	–	x	–	–
„ sp.	x	–	–	–	–
Avellana cassis, *d'Orb.*	x	–	x	–	–
„ hugardiana (in phosphate)	x	–	–	–	–
Cerithium sp.	x	–	x	–	–
Dentalium sp.	–	–	x	–	–
Fusus bilineatus ? *P. and R.*	x	–	–	–	–
Pleurotomaria Gibbsi ?, *Sow.*	x	–	–	–	–
„ brongniartiana, *d'Orb.*	x	–	–	–	–
„ perspectiva, *Mant.*	–	x	x	–	–
Solarium granulatum, *Mant.*	x	x	x	–	–
„ ornatum ? *Sow.* (in phos.)	x	–	–	–	–
„ sp.	x	–	–	–	–
Trochus rotomagensis, *d'Orb.* (in phos.)	x	–	–	–	–
„ sp.	–	–	x	–	–
Turritella cenomanensis ? *d'Orb.*	–	–	x	–	–
Turbo sp. (large)	x	–	–	–	–
„ sp. (small)	x	–	–	–	–
Lamellibranchiata.					
Aucellina gryphæoides, *Sow.*	x	–	–	–	–
Ostrea frons, *Park.* (=carinata, *Sow.*)	x	x	–	–	–
„ acutirostris, *Nilss.*	–	–	–	x	–
„ vesicularis, *Lam.*	x	x	–	x	x
„ vesiculosa, *Sow.*	x	–	–	–	–
Exogyra conica, *Sow.*	x	x	–	–	–
„ haliotoidea, *Sow.*	x	x	x	x	x
Inoceramus latus, *d'Orb.* non *Mant.*	x	x	–	–	–
„ striatus, *Mant.*	b	–	–	–	–
„ tenuis, *Mant.*	–	x	–	x	–
Lima aspera, *Mant.*	x	x	x	–	–
„ elongata, *Sow.*	–	x	x	–	–
„ globosa, *Sow.*	x	x	x	x	–
„ semiornata, *d'Orb.*	b	–	–	–	–
Pecten Beaveri, *Sow.*	–	x	x	x	–
„ elongatus ? *Lam.*	–	x	x	–	–
„ orbicularis, *Sow.*	x	x	x	–	–
„ (Neithea) quinquecostata, *Sow.*	x	x	–	x	–
Modiola reversa ? *Sow.*	x	–	–	–	–
Plicatula inflata, *Sow.*	x	–	–	–	–
„ sigillina, *Woodw.*	x	–	–	–	–
Spondylus latus, *Mant.*	–	x	–	–	–
„ gibbosus (?), *d'Orb.*	x	–	–	–	–
Arca, like carinata, *Sow.*	x	–	x	–	–
„ (Cucullæa) obesa, *Sow.*	x	–	–	–	–
Cardita tenuicosta ?, *Sow.*	x	–	x	–	–
„ sp.	x	–	–	–	–
Cardium, sp.	–	–	x	–	–
Corbis gaultina ? (in phosphate)	x	–	–	–	–
Cytherea, like plana, *Sow.*	–	–	–	–	–
Teredo amphisbæna, *Goldf.*	x	–	–	–	–
Pholadomya decussata, *Phil.*	–	–	x	–	–
Radiolites Mortoni, *Mant.*	–	–	x	–	–
Unicardium ringmeriense, *Mant.*	–	–	x	–	–

List of Fossils from the Lower Chalk, Eastbourne.—*contd.*

—	Bed 1.	Bed 2.	Bed 3.	Bed 4.	Bed 5.
Brachiopoda.					
Kingena lima, *Defr.*	x	x	x	—	—
Rhynchonella grasiana, *d'Orb.*	x	x	—	—	—
,, mantelliana, *Sow.*	—	x	x	—	—
,, Martini, *Mant.*	x	x	—	—	—
,, lineolata, *Phil.*	—	x	x	—	—
Terebratula biplicata, *Sow.*	x	—	—	—	—
,, obesa, *Sow.*	—	x	—	—	—
,, semiglobosa, *Sow.*	x	x	x	x	—
,, squamosa, *Mant.*	—	x	—	—	—
Terebratulina triangularis ? *Eth.*	x	x	—	—	—
,, striata, *Wahl.*	x	x	—	—	—
Crustacea.					
Enoploclytia Leachi, *Mant.*	—	—	—	x	—
,, sussexiensis, *Mant.*	—	x	—	x	x
,, sp.	x	—	—	—	—
Hoploparia sp.	x	—	—	—	—
Palæga Carteri, *H. Woodw.*	—	x	—	—	—
Annelida.					
Serpula annulata, *Reuss*	—	x	x	x	—
,, plexus, *Sow.*	x	x	—	x	—
,, umbonata, *Sow.*	x	x	x	x	—
Echinodermata.					
Cidaris vesiculosa, *Goldf.*	—	—	—	x	—
Discoidea cylindrica, *Lam.*	—	—	—	x	—
,, subuculus, *Klein*	x	—	—	x	—
Epiaster sp.	—	b	—	—	—
Holaster lævis, *Ag.*, var. carinatus	—	x	—	x	—
,, trecensis, *Leym.*	—	x	—	—	—
,, subglobosus, *Leske*	x	x	—	x	—
Pentacrinus Agassizi, *Hag.*	x	—	—	—	—
Pseudodiadema variolare *Brongn.*	—	—	—	x	x
Salenia Clarki, *Forbes*	—	—	—	x	—
,, petalifera, *Desm.*	—	—	—	x	—
,, sp.	—	—	—	x	—
Cœlenterata.					
Bathycyathus Sowerbyi, E. & H.	x	—	—	—	—
Micrabacia coronula, *Goldf.*	x	x	x	x	—
Craticularia Fittoni, *Mant.*	x	x	—	—	—
Hexactinellid Sponge (? new)	x	—	—	—	—
Hylospongia sp.	x	—	—	—	—
Leptophragma sp. (in phosphate)	x	—	—	—	—
Nelumbia sp.	—	x	—	—	—
Phymatella intumescens, *Roemer*	—	x	—	—	—
,, sp.	x	—	—	—	—
Plocoscyphia labrosa, *Smith*	x	x	—	—	—
,, reticulata, *Hinde*	x	—	—	—	—
,, new sp.	x	—	—	—	—
,, (small sp. in phosphate)	x	—	—	—	—
Siphonia tulipa, *Zitt.*	x	—	—	—	—
Stauronema Carteri, *Sollas*	x	—	—	—	—
Strephinia convoluta, *Hinde*	x	—	—	—	—
Ventriculites tesselatus ? *Smith*	x	—	—	—	—

CHAPTER VII.

THE LOWER CHALK IN THE ISLE OF WIGHT.

General Description.

The Lower Chalk of the Isle of Wight is comparable in its main features with that of Kent and Sussex, and many fossils have been obtained from its lower beds by various collectors, but no one has yet made a detailed study of their distribution, with a view of ascertaining whether it is divisible into definite beds or bands characterised by the prevalence of certain species, as in the case of the Folkestone Chalk.

By the older geologists the greater part of the Lower Chalk of the island was called Chalk Marl, and their Lower Chalk included the zone of *Holaster subglobosus*, together with the whole of the Middle Chalk, which is here without flints.

The first attempt to divide the Chalk of the Isle of Wight into zones was by Professor C. Barrois,* who recognised the equivalent of the zone of *Ammonites varians*, and of the division which he and M. Cheillonneix had termed the zone of *Am. cenomanensis* in the Pas de Calais, but he makes no mention of the highest part of the stage, nor of the Belemnite Marl, giving the total thickness as only 35 metres (about 115 feet), which is much under the mark.

Until the publication of the second edition of the Survey Memoir on the Isle of Wight,† no correct measurement of the beds that make up the Lower Chalk had ever been made. This was done by Mr. Strahan, who measured the component beds in the cliffs west of Culver Point, and found them to be about 205 feet thick, without including the Chloritic Marl at the base or the Belemnite Marls at the top. He divided this mass of Chalk into three parts, with relative thicknesses of 70, 50, and 86 feet, and it is undoubtedly true that the Lower Chalk is capable of such lithological subdivision at that locality, as it is at Folkestone and near Wissant on the French coast, but we do not think it comprises more than two zones at any locality. We do not find a sufficient difference in the faunas of the lower and middle parts to warrant their recognition as separate zones, and the collections made for this Memoir have proved that *Ammonites* [*Schloenbachia*] *varians* ranges up through fully 100 feet from the base.

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* Craie de l'Ile de Wight. Bibl. des Hautes Études, tom. xiii., 1875.

† Bristow "Geology of the Isle of Wight," Ed. 2, by C. Reid and A. Strahan, 1889.

We shall therefore regard the Lower Chalk of the island as comprising only two zones, regarding the beds known as the Chloritic Marl and the Belemnite Marl as subsidiary divisions or subzones. Eventually some other sub-zones may be established, such as that of *Plocoscyphia labrosa*, proposed by Professor Barrois, and possibly a higher one characterised by abundance of *Scaphites æqualis* and *Turrilites costatus*. The following table indicates the scheme of arrangement which may perhaps be found applicable:—

Zone of *Holaster subglobosus*	Marl with *Actinocamax plenus*. Chalk with few fossils, *Holaster trecensis* and *Discoidea cylindrica*.
Zone of *Ammonites varians*	Beds with *Turrilites costatus*. Beds with *Scaphites æqualis*. Beds with *Plocoscyphia labrosa*. Beds with *Stauronema Carteri*.

The basement beds with *Stauronema Carteri* are those which have usually been known as the Chloritic Marl, and have been the subject of much discussion. Some account of this discussion has been given in Chapter II., and much difficulty has been experienced in determining at what particular horizon the line between the Upper Greensand and the Chalk should be drawn. There is undoubtedly a series of passage beds, and if they are regarded merely as a set of beds, without reference to the distribution and range of fossils, different observers would be likely to draw the line at different horizons, and even when the fossils have been carefully collected it is not very easy to decide what beds should be included in the Chloritic Marl or zone of *Stauronema Carteri*.

Moreover the sections to which previous descriptions have referred are those of the Undercliff, and no attempt has hitherto been made to correlate the exposures at each end of the Undercliff with one another and with those in Compton Bay and Culver cliffs. All these differ considerably in detail, and no such attempt would be successful unless the fossils obtainable from each bed were carefully collected at the same time.

An endeavour was made to do this in 1897, and after a careful examination of the principal sections, Mr. Rhodes was directed to collect carefully from the several beds at the different localities. We have thus obtained better palæontological evidence than any geologist has hitherto had at his disposal, but nevertheless we have not found it easy to make up our minds as to the exact horizon which should be taken as the base of the Chloritic Marl. In such a matter the result must very much depend on the value which is put upon the evidence of particular fossils. We have elsewhere given reasons for considering *Pecten asper* as an unreliable guide; as a matter of fact in the Isle of Wight it does not occur in the Chert Beds of the Selbornian, but is found in a perfect state of preservation throughout the Chloritic Marl. Again, *Am.* [*Schloenbachia*] *varians*, though generally a good guide, is known to occur both in Wiltshire and North Dorset below what must be regarded as the local base of the Chalk. *Am.* [*Schl.*] *rostratus,* on the other hand, has never yet been found (underived) in any bed which could be referred to the Chloritic Marl, and it is very rarely found in the higher beds of the Greensand. The species which we have found to be the most reliable guide is *Stauronema Carteri.* The range of this species appears to be very limited; it is common in the bed which has always been regarded by the Geological Survey as typical Chloritic Marl. It occurs up to 14 feet above this bed at Culver, and has been found by Mr. Rhodes and Mr. J. B. Hue in the beds which underlie the phosphatic bed (those numbered 3 and 4 by us), and Mr. Hue has found a specimen in the still lower bed (2) near Ventnor. But it has never been found below this. So far, therefore, as *Stauronema Carteri* may be relied upon, its evidence leads us to include this lower bed with the Chloritic Marl, and to regard it as the basement bed of the Lower Chalk.

It is exactly this point which makes the enquiry of importance, for otherwise it might seem a trivial matter whether a foot or so of material were or were not classed under the head of Chloritic Marl; but when we remember that if it is so classed all the fossils it contains will have to be regarded as Lower Chalk fossils, and will have to be excluded from the list of Selbornian fossils, then it will be seen that no pains should be spared in collecting and weighing the evidence.

During the examination of the sections in 1897 and 1898 several important facts were observed which have enabled us to correlate the sections seen at different localities with one another. In the first place it was noticed that in every section, at what appeared to be the same horizon, there was an appreciable change in the character and colour of the rock-material; the bed below this plane being light grey or yellowish green, and less glauconitic, that above it being greyish-green and very glauconitic; moreover, the lower bed is generally piped and mottled with the darker material, as if filled with holes and borings which had been made in the lower bed before the deposition of the upper bed. This recalls the relation of the zone of *Stauronema Carteri* at Folkestone to the underlying Gault, though the materials do not contrast so markedly as at Folkestone. Moreover on the western side of the island there are indications of current erosion at the same horizon, the bored surface being also an uneven surface with hollows which are sometimes 15 to 18 inches in maximum depth.

On a more recent visit (May, 1898) Mr. Hill paid special attention to the beds at this horizon, and examined the large fallen masses on the shore between Ventnor and Rocken End. Starting from the Ventnor section, which was published by us in 1896,* he found that the bed which was then numbered 3 could be recognised in all the exposures to the westward. This is a nodule-bed, enclosing lumps of hard fine-grained calcareous sandstone, which have been phosphatised to the depth of half an inch or more, and are frequently bored by lithophagous Mollusca; these lumps are seldom larger than a cricket ball, but generally oval, and mingled with them are phosphatic nodules, phosphatised sponges belonging chiefly to *Jerea* and *Hallirhoa*, and broken shells of *Pecten asper*, with occasionally other fossils. It is this bed which rests on an eroded surface in the more western sections at Rocken End, Brook, and Compton Bay, and it was in this bed that Mr. Rhodes found *Stauronema Carteri* at Compton Bay.

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* See Quart. Journ. Geol. Soc., Vol. lii. p. 105.

Further, Mr. Hill ascertained that the bed which overlies it at Ventnor (No. 4) is the most variable bed in the whole group, being sometimes as much as 3 feet thick, and sometimes thinning out altogether. In this bed fragments of *Stauronema* have also been found by Mr. Hue, of Ventnor. *Am.* [*Schlœnbachia*] *varians* also occurs but rarely, and, indeed, fossils are always rare in this discontinuous intermediate bed.

In consequence of these fresh discoveries we have modified the opinion expressed in the paper above mentioned, and, finding that the nodule-bed coincides with the downward range of *Stauronema Carteri*, we have adopted it as the basement bed of the Chalk in the Isle of Wight. At the same time, what was then said about the sudden incoming of an abundant Ammonite fauna at a higher horizon (Bed 5) is perfectly true, for it is only *Am.* [*Schl.*] *varians* that occurs in the lower beds, and only in Bed 5 that the other species of *Ammonites* and *Turrilites* make their appearance. Even should one or two be hereafter found, below, they can only occur as rare fossils, and the contrast between the beds will remain as strong as before.

We continue to use the name Chloritic Marl because it is a convenient designation and has been so long in use, but it is a bad name for the bed, not only because the green grains are not chlorite, but because the matrix is not a marl; the lower beds are glauconitic sands, the highest bed is a hard glauconitic sandy chalk, with but a small quantity of argillaceous matter. This bed is sometimes overlain by a layer of grey marl containing glauconite grains, and in other localities it passes up into grey glauconitic and sandy chalk, in which *Plocoscyphia labrosa* is abundant and *Turrilites tuberculatus* is not uncommon.

The *Plocoscyphia* beds are succeeded by alternating beds of hard grey chalk and soft marly chalk, the marly beds becoming thinner and less conspicuous in the upper part of the series. These beds contain many fossils, and form the mass of the zone of *Ammonites varians*, that species being associated with *Am.* [*Acanth.*] *rotomagensis* and *Am.* [*Acanth.*] *Mantelli.*

The higher part of the Lower Chalk consists of nearly white chalk in massive beds, extending, with little change, up to the Belemnite Marl, and having a thickness of 85 to 90 feet. This white chalk is lithologically comparable to the whitish chalk which forms the upper 50 feet of the Folkestone section, which it also resembles in containing but few fossils. Stratigraphically, however, it appears to represent the whole of the zone of *Holaster subglobosus*, and not only a portion of it. At the summit is a band of grey marl, which clearly represents the Belemnite Marl, though no specimen of *Actinocamax* has yet been obtained from it.

As regards thickness, the total amount in Culver cliff is about 211 feet, but it decreases westward, and is only 161 feet in Compton Bay, the difference being principally in the zone of *Am. varians*.

STRATIGRAPHICAL DETAILS.

1. Chloritic Marl.

We now give the sections and particulars upon which the above remarks are based, beginning at the eastern end of the island:—

SECTION IN CULVER CLIFF.

		ft.	in.
Chloritic Marl. 8½ feet.	5A. Bluish-grey glauconitic marly chalk, with brown phosphate nodules and lumps of hard calcareous stone in two beds	4	6
	5. Greenish glauconitic sandy marl, with an irregular layer of hard concretions at top; many brown phosphates and fossils	3	0
	3. Layer of grey calcareous doggers, with a few phosphatised stones embedded in grey sand - - - - from 6 inches to	1	0
Selbornian.	2. Grey sand with an irregular surface, pierced by pipes and borings, infilled with dark green glauconitic sand; from 6 inches to	1	0
	1. Sand with concretions of calcareo-siliceous stone (see Vol. I., p. 138).		

From No. 3 Mr. Rhodes obtained the following:—*Hallirhoa agariciformis*, *Stauronema Carteri*, and *Pecten asper*. The bed which we have numbered 4 at Ventnor is absent at Culver. From No. 5: *Plocoscyphia fenestrata*, *Stauronema Carteri*, *Pecten asper*, *Am.* [*Schloenbachia*] *varians*, and many other fossils have been obtained.

Passing now to the Undercliff, we come first to a quarry under St. Boniface Down, near Ventnor, and here the following section was very clearly shown in 1897:

		ft.	in.
Chalk Marl.	Chalk Marl	15	0
	Two beds of hard grey chalk separated by 6 inches of marl	2	6
	Soft grey marl, slightly glauconitic	0	6
Chloritic Marl. 7 feet.	5. Firm greenish glauconitic sandy marl, full of phosphatic nodules and casts of fossils; Ammonites abundant	3	0
	4A. Firm greenish sandy marl with some hard concretionary lumps; a few phosphates	1	3
	4. Very glauconitic sandy marl; no phosphates or Ammonites seen	2	0
	3. Layer of hard stony concretions with brown phosphatised crusts - from 6 inches to	0	9

			ft.	in.
Selbornian.	2.	Firm yellowish-green glauconitic sand, piped with darker sand from above, "the piped bed"	1	6
	1.	Sand containing brown-coated stony concretions - - - - - - - -	1	6
		Irregular layer of grey chert - about	0	3
		Concretions of calc. sandstone with thick brown crusts - - - - -	1	0
		Chert Beds below.		

If this succession is compared with that given by us in 1896, as shown on the shore below Ventnor,* it will be found to correspond very closely, the corresponding beds being indicated by the same numbers. As compared with the Culver section, it will be seen that two beds, with a combined thickness of over 3 feet, have come in between Nos. 3 and 5. The highest bed, No. 5, might be called the Cephalopoda-bed, and it exhibits the same characters all along the Undercliff.

The section at St. Lawrence Shute is important in showing the diminution of Bed 4, and is as follows:—

			ft.	in.
Chloritic Marl. 4¼ feet.	5.	Glauconitic marl with *Ammonites* and phosphatic nodules - - - - - - -	3	0
	4.	Rather soft greenish-grey sandy marl, with few nodules or fossils - - - - -	0	6
	3.	Layer of phosphatised stony concretions, about as large as a cricket ball, and some phosphates, - - - - - 6 inches to	0	9
Selbornian.	2A.	Fine glauconitic sandy marl with an irregular layer of stony concretions, - about	1	0
	2.	Hard greenish-grey marly sand piped with darker material, and containing many *Pecten orbicularis* - - - - - - -	2	0
	1.	Layer of compact calcareous doggers - -	1	0
		Firm grey sand with cherts - seen for 12 or	15	0

It will be noticed that about a foot of sandy marl with the stony concretions (which might perhaps be called cornstones) here intervenes between the " piped bed " and the nodule-bed, No. 3.

At Binnell Point, about three-quarters of a mile west of St. Lawrence Shute, the junction beds are shown in a slipped mass, and here there is nothing to represent Bed 4, so that the nodule-bed (3) forms the base of the Cephalopoda-bed (5):—

		ft.	in.
5.	Glauconitic marl with Cephalopoda - - -	3	0
3.	Nodule-bed with green and brown coated lumps - -	0	9
2A.	Greenish-grey sand with a few scattered cornstone lumps at and near the base - - - -from 1 to	1	3
2.	Greyish-green sand with darker pipings—*Pecten orbicularis* and *P. asper* - - - - - - -	1	0

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* Quart. Journ. Geol. Soc., Vol. lii. p. 105.

At Rocken End there are several large masses which must have fallen originally from St. Catherine's cliff, and one of these showed the following beds :—

		ft.	in.
Chloritic Marl. 4¼ feet.	5. Glauconitic marl with many phosphatic nodules and Cephalopoda	3	6
	3. Nodule-bed, more developed than usual, with brown phosphatised cornstone lumps and phosphatic nodules, which are often greenish outside	0	9
Selbornian.	2. Greenish glauconitic sand with a few brownish phosphates and many *Pecten orbicularis ;* pipings filled with sand from above are conspicuous	1	3
	Hard grey sand with larger phosphatised lumps of stone irregularly placed - about	1	6
	Firm grey glauconitic sand with cornstones	3	0
	Layer of massive blocks or lumps of calcareous sandstone	1	0
		11	0

Each fallen mass exhibits minor differences, which are chiefly due to the varying amount of erosion at the base of No. 3. Mr. Rhodes when collecting fossils here noticed that the nodule-bed varied from 6 to 18 inches in depth, and rested on a correspondingly uneven and undulating surface of the bed below. He found also that the pipes or bore-holes from this bed penetrated in some cases for a depth of 12 inches, and he obtained *Am.* [*Schl.*] *varians* and a piece of a *Baculites* from the bottom of a boring of that depth. Without careful observation, therefore, these fossils might have been recorded as belonging to Bed 2.

The Chloritic Marl can be reached at the top of Gore cliff, but is not very easy of access ; the section appears to tally with that just given.

At Brook Shute, 7½ miles north-west of St. Catherine's Hill, the thickness of the Chloritic Marl has greatly increased, and from the particulars given below it will be seen that the Bed No. 4 reappears at this place :—

	ft.	in.
5. Very glauconitic sandy marl, full of phosphatic nodules and casts of fossils, with some well-preserved *Pecten asper ;* also many hard concretionary lumps	8	0
4. Softer and more sandy glauconitic marl, with only a few phosphates and no other concretions; one *Am.*[*Schloenb*] *varians* found	3	0
3. Nodule-bed with the usual phosphatised lumps, some of which are large, and many are bored by lithophagous Mollusca ; these lumps are sometimes in one layer, sometimes in two layers, and the bed rests on an uneven surface of the sand below - 1 to	1	6
2. Greenish-grey sand, eroded and piped (see p. 81).		
Total about	12	0

The section in Compton Bay is almost the same, differing only in the thickness of the beds. In abstract it is thus:—

		ft.
Chloritic Marl.	5. Glauconitic marl with many phosphates and Cephalopods - - - - - -	6
	4. Sandy marl without phosphates, *Stauronema* common - - - - - - - -	$3\frac{1}{2}$
	3. Nodule bed as at Brook, from 6 inches to -	1
	2. Greenish-grey sand, piped as before - - - -	1

The nodule-bed here contains many fossils, and in it Mr. Rhodes found two *Stauronema Carteri* in good preservation. Mr. J. B. Hue has also obtained fossils from all three beds.

LIST OF FOSSILS FROM THE CHLORITIC MARL.

The following list is not intended to be a complete list of all the fossils which have been recorded from the Chloritic Marl of the Isle of Wight, but only of those for which we have good authority for referring to their exact horizon, that is, to one or other of the three distinct beds which we now include under this name. The list is based on that which we published in 1896,* with a few corrections and many additions. The additions are due to collections made by Mr. Hill, and subsequently by Mr. Rhodes, for the Geological Survey, and partly to the identification of species in the collection of Mr. J. B. Hue, of Ventnor, who has collected from the several beds, and has kindly sent many of his specimens for determination.

The localities are indicated by letters as follows:—

a=Culver cliff.
b=Ventnor, Bonchurch, and St. Lawrence.
c=Niton, Gore cliff, and Rocken End shore.
d=Brook and Compton Bay.

The species added on Mr. Hue's authority are indicated by the letter h, because they were obtained from various places along the Undercliff, though most of them came from near Ventnor.

——	Bed 3.		Bed 4.		Bed 5.		
Pisces.							
Lamna appendiculata, *Ag.* - - - - - - - -	b	–	–	d	b	c	–
Scapanorhynchus rhaphiodon, *Ag.* - - - - - -	–	–	–	–	b	–	–
Cephalopoda.							
Ammonites [Placenticeas] complanatus, *Sow.* - -	–	–	–	–	h	–	–
„ [Hoplites] curvatus, *Mant.* - - - -	–	–	–	–	h	–	–
„ [„] falcatus, *Mant.* - - - -	–	–	–	–	h	–	–
„ [Acanthoceras] laticlavius, *Sharpe* - -	–	–	–	–	h	–	–
„ [„] Mantelli. *Sow.* - - -	–	–	–	–	a b	c	d
„ [„] navicularis, *Mant.* - -	–	–	–	–	a b	c	d
„ [Desmoceras] planulatus, *Sow.* - - -	–	–	–	–	h	–	–
„ [Hoplites] Saxbyi, *Sharpe* - - - -	–	–	–	–	b	–	–
„ [Schloenbachia] varians, *Sow.* - - -	–	c	–	d	a b	c	d
„ „ Coupei, *Brongn.* - - -	–	–	–	–	a b	c	d
Anisoceras alternatum, *Mant.* - - - - - - -	–	–	–	–	b	–	–
„ augustum, *Mant.* - - - - - - -	–	–	–	–	h	–	–
„ pseudelegans, *P. & C.* - - - - - -	–	–	–	–	b	–	–
Baculites baculoides, *Mant.* - - - - - - -	–	–	–	–	h	–	–
„ sp. - - - - - - - - - - -	–	c	–	d	–	–	–
Hamites simplex *d'Orb.* - - - - - - - -	–	–	–	–	h	–	–
Turrilites Bergeri, *Brongn.* - - - - - - -	–	–	–	–	b	c	d
„ Morrisi, *Sharpe* - - - - - - -	–	–	–	–	a b	c	d
„ tuberculatus, *Bosc.* - - - - - - -	–	–	–	–	b	c	–
„ Wiesti, *Sharpe* - - - - - - - -	–	–	–	–	b	c	–
Nautilus deslongchampsianus, *d'Orb.* - - - -	–	–	–	–	b	–	–
„ expansus, *Sow.* - - - - - - - -	–	–	–	–	b	–	d
„ sublævigatus, *Sow.* - - - - - - -	b	–	–	–	b	c	–
Gasteropoda.							
Actæon elongatus, *Sow.* - - - - - - - -	–	–	–	–	b	–	–
Avellana cassis, *d'Orb.* - - - - - - - -	–	c	–	–	b	–	d
Cerithium sp. - - - - - - - - - -	–	–	–	–	h	–	–
Columbellina sp. - - - - - - - - -	–	–	–	–	h	–	–
Murex bilineatus, *P. & C.* - - - - - - -	–	–	–	–	h	–	–

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*Quart. Journn. Geol. Soc., Vol. lii. p. 105.

List of Fossils from the Chloritic Marl.—*contd.*

—	Bed 3.		Bed 4.		Bed 5.		
Gosteropoda.							
Pleurotomaria brongniartiana, *d'Orb.*	b	c	–	–	a b	c	d
„ mailleana, *d'Orb.*	–	–	–	–	h	–	–
„ perspectiva, *Sow.*	–	–	–	–	b	c	–
„ sp.	–	d	–	–	–	–	–
Scalaria sp.	–	–	–	–	h	–	–
Solarium bicarinatum, *Tiessen*	–	–	–	–	h	–	–
„ dentatum, *Sow.*	–	–	–	–	h	–	–
„ ornatum, *Sow.*	–	c	–	–	b	c	d
Turbo sp.	–	–	–	–	h	–	–
Lamellibranchiata.							
Aucellina gryphæoides, *Sow.*	–	–	–	–	b	–	d
Arca pholadiformis, *d'Orb.*	–	–	–	–	h	–	–
„ royana ? *d'Orb.*	–	–	–	–	b	–	–
Cucullæa mailleana, *d'Orb.*	–	d	–	–	b	c	–
„ obesa ? *P. & R.*	–	–	–	–	b	c	–
Cardium (small sp.)	–	–	–	–	b	–	–
Cardita cf. tenuicosta, *Sow.*	–	c	–	–	–	c	–
Crassatella sp. (casts)	–	–	–	–	b	–	–
Cyprina quadrata, *d'Orb.*	–	–	–	–	d	–	–
„ sp.	–	–	–	–	b	–	–
Exogyra conica, *Sow.*	–	d	–	–	h	–	d
„ haliotoidea, *Sow.*	–	–	–	–	b	–	d
Inoceramus latus, *d'Orb.*	–	–	–	–	b	c	–
Lima globosa, *Sow.*	h	–	–	–	b	–	d
„ rauliniana ? *d'Orb.*	–	c	–	–	h	–	–
„ sp.	–	–	–	–	h	–	–
Nucula obesa, *d'Orb.*	–	–	–	–	b	–	–
Ostrea canaliculata, *Sow.*	–	–	–	–	h	–	d
„ frons, *Park*	–	c d	–	–	–	–	–
„ normaniana, *d'Orb.*	–	–	–	–	h	–	–
„ vesicularis, *Lam.*	b	c	–	–	b	c	–
„ vesiculosa, *Sow.*	b	c	b	d	b	–	d
Pecten asper, *Lam.*	a b	c d	b ?	–	a b	c	d
„ Beaveri, *Sow.*	–	–	–	–	b	c	–
„ elongatus, *Sow.*	–	–	h	–	b	–	–
„ orbicularis, *Sow.*	h	d	–	–	b	–	d
„ robinaldinus, *d'Orb.*	–	–	–	–	h	–	d
„ puzosianus, *d'Orb.*	b	–	–	–	–	–	–
„ (Neithea) cometa, *d'Orb.*	h	d	–	–	h	–	d
„ „ quinquecostatus, *Sow.*	b	–	b	–	h	–	d
Plicatula gurgitis, *P. & R.*	–	c d	b	d	b	c	d
„ „ var. inflata, *Sow.*	–	–	–	–	h	–	–
Spodylus latus, *Sow.*	–	–	–	–	h	–	–
„ sp.	–	c d	–	–	–	–	–
Unicardium ringmeriense, *Mant.*	–	–	–	–	b	–	–
Venus rotomagensis, *d'Orb.*	–	–	–	–	h	–	–
Brachiopoda.							
Crania cenomanensis, *d Orb.*	–	–	–	–	h	–	d
Kingena lima, *Defr.*	–	–	–	–	b	c	d
Rhynchonella dimidiata, *Sow.*	–	d	–	–	–	–	–
„ grasiana, *d'Orb.*	–	–	–	d	a b	–	d
„ mantelliana, *Sow.*	–	–	–	–	h	(one)	d
„ Martini, *Mant.*	–	–	–	–	b	–	–
Terebratula biplicata, *Sow.*	b	–	b	–	b	–	d
Terebratella pectita, *Sow.*	–	c	–	–	b	–	–
Terebratulina striata, *Wahl.*	h	–	–	–	b	–	d
Annelida.							
Serpula umbonata, *Sow.*	–	–	h	–	b	–	–
„ (several species)	–	–	–	–	h	–	–
Echinodermata.							
Cardiaster fossarius, *Benett*	b	c	–	–	–	–	–
Cidaris dissimilis, *Forbes* (spine)	–	–	–	–	b	–	–
Discoidea subuculus, *Klein*	–	d	h	d	b	c	d
Glyphocyphus radiatus, *Hoen.*	–	–	–	–	h	–	–
Hemiaster Morrisi, *Forbes*	–	c	–	–	b	–	–
Holaster lævis, *Ag.*	b	c	–	–	–	–	–
Salenia sp. (cf. Austeni, *Forbes*)	–	–	–	–	h	–	–
„ petalifera, *Desm.*			–	–	h	–	–
Actinozoa.							
Micrabacia coronula, *Goldf.*	–	–	–	–	b	–	–
Bathycyathus Sowerbyi, *Ed. & H.*	–	–	–	–	b	–	–
Spongida.							
Callopegma sp.	–	–	–	d	h	–	–
Hallirhoa agariciformis, *Benett* (phosphatic)	a b	c d	–	–	–	–	d
Jerea Websteri, *Sow.* (phosphatic)	–	c	–	d	–	–	–
Plocoscyphia fenestrata, *T. Smith*	–	–	–	–	a b	c	d
„ labrosa, *T. Smith*	–	–	–	–	h	c	d
„ reticulata, *Hinde*	–	–	–	–	b	–	d
Porosphæra sp	–	–	–	–	b	–	–
Siphonia tulipa, *Zitt.*	–	c d	–	–	–	–	–
Stauronema Carteri, *Sollas*	a	d	b	d	a b	c	d

The Mass of the Lower Chalk.

We will now give some account of the principal sections in or through the Lower Chalk.

It will be convenient to begin at the eastern end of the island, as the whole stage is well exposed in the cliffs near Culver Point. This section was measured by Mr. Strahan in 1889, and by Mr. Hill (for this Memoir) in 1897, and they differ little as to total thickness, but the subjoined account gives rather more detail than the older one:—

		ft.
Zone of *H. subglobosus*	7. Soft bluish-grey marl (sub-zone of *Act. plenus*) about	6
	6. Firm white chalk, breaking into a smooth fracture, in massive beds; contains *Holaster subglobosus*, *H. trecensis*, *Discoidea cylindrica* - - - -	85
Zone of *Am. varians.*	5. Grey chalk in regular courses, weathering as ribs under the wash of the sea - - - about	45
	4. Bluish-grey marly chalk with harder courses of grey chalk, which weather out as strong ribs under the wash of the sea - - - - - about	40
	3. Soft bluish-grey marl, passing down into firmer sandy marl, with *Plocoscyphia labrosa* - about	15
	2. Harder bluish sandy marl, with masses of *Plocoscyphia labrosa* and some fragments of brown phosphate—*Am.* [*Schloenb*] *varians*, *Serpula umbonata*, and other fossils- - - about	12
	1. Chloritic Marl in four beds (see p. 83) - -	8
	About	211

No. 1, the zone or niveau of *Stauronema Carteri*, has already been described. Nos. 2 and 3 are the beds which Dr. Barrois terms the zone of *Plocoscyphia mæandrina* (=*labrosa*). These three beds, taken together, are the equivalents of Beds I. and II. at Folkestone. Beds 4 and 5 are those which have often been called "the Grey Chalk," but they do not possess any special palæontological characters; *Am.* [*Schl.*] *varians* ranges from No. 1 into No. 5, and consequently all these beds fall into the zone of *Am. varians*.

No. 6 is the massive white chalk already mentioned (see p. 82), and No. 7 is the sub-zone of *Actinocamax plenus*, though that fossil has not been found here.

Another excellent section of nearly the whole of the Lower Chalk is to be seen in Mr. Mumm's quarry, 300 yards west of Yarbridge, which must have been deepened considerably since Mr. Strahan's visit, since it showed the following succession in 1897:—

		ft.	in.
Middle Chalk.	Hard white bedded chalk, with *Inoceramus mytiloides* and *Rhynchonella Cuvieri* - - - more than	20	0
	Hard rough white nodular chalk, divided into thinnish beds by marly partings - - -	5	0
	Rough white nodular chalk - - - - - - -	1	6
	Greenish-grey marl - - - - - - - -	0	2
	Hard rough whitish nodular chalk, veined and streaked with greenish-grey -	4	6

		ft.	in.
Lower Chalk.	Grey marl, hard and firm, but weathering into platy pieces	4	6
	Rather hard white chalk, apparently without fossils, in massive blocks - about	90	0
	Greyish-white chalk, in courses divided by layers of marly chalk, but the courses are less strongly marked than those below — *Scaphites æqualis* and other fossils - about	40	0
	Grey chalk in alternating hard and marly courses. *Am.* [*Schloenb.*] *varians* common throughout -	55	0

The actual base is not seen, but the Chloritic Marl occurs in the lane adjoining the pit, and there is probably not more than a thickness of 10 or 15 feet between this and the base of the quarry section.

Passing to the southern part of the island, many small exposures of the lower beds of this stage will be found round the borders of the outlying mass which caps the Upper Greensand, and also in the fallen masses which lie on the Undercliff or along the southern shore.

In 1880 one of us saw a good section in a quarry near Jolliff's Farm at Luccombe; this showed alternating beds of hard, compact, grey chalk and soft shaly marl, with many fossils in the hard bands, such as *Turrilites costatus, Am.* [*Acanth.*] *Mantelli, Baculites baculoides, Scaphites æqualis,* and *Inoceramus latus* (d'Orb). About 16 feet of these beds were seen, and in the roadway leading to the quarry were beds of darker grey, rather hard sandy or gritty chalk, with *Am.* [*Schloenb.*] *varians, Plicatula gurgitis, Rhynchonella mantelliana,* and pieces of brown phosphate. This horizon is probably not far above the Chloritic Marl.

The lower part of the Chalk Marl, with the Chloritic Marl at its base, may be examined at the top of St. Lawrence Shute, and again at the top of Gore cliff, above South View House. More than 50 feet of the alternating hard and soft beds are exposed at St. Lawrence, and about 41 feet at Gore cliff. Many fossils were collected by Mr. Rhodes at these localities,

Brook Shute is another place where the zone of *Ammonites varians* may be examined, about 100 feet of chalk being there exposed above the Chloritic Marl.

The only other complete section of the Lower Chalk is that in Compton Bay, which was measured by Mr. Hill in 1897, and found to be as follows:—

	ft.
Hard smooth grey marl, passing down rapidly into white chalk (sub-zone of *Act. plenus*)	9
Greyish-white chalk in well-marked courses, divided by seams of marl; *Holaster subglobosus* and *Hol. trecensis*?	90
Grey chalk in alternating soft and harder courses; light grey above, bluish-grey below	40
Grey chalk with many small brown phosphatic nodules	1½
Bluish-grey slightly glauconitic chalk	10
Chloritic Marl (see p. 86)	10½
About	161

In the 10 feet above the Chloritic Marl Mr. Rhodes found *Am.* [*Schloenbachia*] *varians*, *Am.* [*Acanth.*] *Mantelli*, *Turrilites Wiesti*, *Plocoscyphia fenestrata*, and *Pl. reticulata*; and at 40 feet from the top of the Chloritic Marl he obtained a large *Am.* [*Schloenbachia*] *varians* and *Holaster subglobosus*.

LIST OF FOSSILS FROM THE CHALK MARL OF THE ISLE OF WIGHT.

The following list of fossils from the Chalk Marl (zone of *Ammonites varians*) is as complete as we have been able to make it. Some 60 feet of this zone is exposed at different places above the Undercliff, and Mr. Rhodes collected carefully from successive horizons in this thickness to ascertain if there was any limitation of species to particular parts of it. The results may be taken to show that some species, such as *Scaphites æqualis*, are more common in the lower part or in certain beds; but many of the species met with at only one or two horizons would doubtless be found at others, if more prolonged search was made. We have, however, tabulated his results for the sake of the record.

The last column includes species which have been previously recorded by Mr. Sharpe in his monograph on Cretaceous Cephalopoda, and by Professor Barrois in his Description of the Isle of Wight, as well as some obtained by Mr. J. B. Hue, of Ventnor, and sent to me for determination. The *Ammonites cinctus* is a fragment obtained by Mr. Hue and is not perfect enough to be free of doubt. The specimen of *Salenia Clarki* was obtained by Mr. J. C. Eccles, who has kindly presented it to the Museum of Practical Geology. Those from Luccombe were obtained by me in 1880.

The localities are indicated by letters, thus:—c=Culver; y=Yarbridge; u=Undercliff; l=Luccombe; b=Brook; f=Compton Bay.

	1 to 7 Feet.	8 to 15 Feet.	20 to 28 Feet.	30 to 46 Feet.	50 to 81 Feet.	Height unknown.
Vertebrata.						
Bone of Pterodactyle	–	–	–	–	–	b
Lamna appendiculata, *Ag.*	–	–	–	–	–	y u b
Ptychodus sp.	–	–	–	–	–	u
Cephalopoda.						
Ammonites [Haploceras] cinctus, *Sharpe*	–	–	–	–	–	u
,, [Acanth.] Deverianus *d'Orb.*	–	–	–	–	–	b
,, [Hoplites] falcatus, *Mant.*	–	–	–	–	–	u
,, [,,] feraudianus, *d'Orb.*	–	–	–	–	–	u
,, [Acanth.] laticlavius, *Sharpe*	–	–	–	–	–	? loc.
,, [Lytoceras] leptonema, *Sharpe*	–	–	–	–	–	u
,, [Acanth.] Mantelli, *Sow.*	f u	c	y	c	–	passim
,,] ,,] navicularis, *Mant.*	y u	u	–	c	–	passim
,, [Desm.] octosulcatus, *Sharpe*	–	–	–	–	–	u
,, [,,] planulatus, *Sow.*	–	–	–	–	–	u
,, [Phylloceras] Pergensi, *de Gross.* (=Am. velledæ, *Sharpe* non *Mich.*)	–	–	–	–	–	u
,, [Hoplites] renauxianus, *Sharpe*, non *d'Orb.*	–	–	–	–	–	u
,, [Schloenb.] Renevieri, *Sharpe*	–	u	–	–	–	u
,, [Acanth.] rotomagensis. *Brongn.*	u	–	–	–	–	u l b
,, [Hoplites] Saxbyi, *Sharpe*	–	–	–	–	–	u
,, [Schloenb.] varians, *Sow.*	c y u	c u	c u	c y f u	c u	passim
,, [,,] Coupei, *Brongn.*	u	c u	c u	c u	–	passim
,, [Prionot.] Woolgari ? *Mant.*	–	–	–	–	c	–
Anisoceras armatus, *Sow.*	–	–	–	–	–	l b
Baculites baculoides, *d'Orb.*	–	–	–	–	–	u l b
Belemnites ultimus, *d'Orb.*	–	–	–	–	–	u
Hamites *armatus* (*see* Anisoceras)	–	–	–	–	–	–
,, sp.	–	–	–	–	–	b
Nautilus deslongchampsianus, *d'Orb.*	–	–	–	–	–	u
,, elegans, *Sow.*	u	u	–	–	–	l u
,, sublævigatus, *d'Orb.*	–	–	–	–	–	u
Scaphites æqualis, *Sow.*	u	u	–	–	–	l x
Turrilites Bergeri, *Brongn.*	u	u	–	–	–	–
,, costatus, *Sow.*	–	–	–	–	–	l u b
,, Mantelli, *Sharpe*	–	–	–	–	–	u
,, Morrisi, *Sharpe*	u	–	–	–	–	b
,, scheuchzerianus, *Bosc.*	u	–	–	c u	c	–
,, tuberculatus, *Bosc.*	u	–	c u	–	–	b
,, Wiesti, *Sharpe*	f	–	–	u	–	b

List of Fossils from the Chalk Marl of the Isle of Wight.—*contd.*

	1 to 7 Feet.	8 to 15 Feet.	20 to 28 Feet.	30 to 46 Feet.	50 to 81 Feet.	Height unknown.
Gasteropoda.						
Actæon affinis, *Sow.*	–	–	–	–	–	b
Aporrhais oligochila, *Gard.*	–	–	–	–	–	u
,, sp.	–	–	–	–	–	b
Avellana cassis, *d'Orb.*	–	–	u	–	–	u
Pleurotomaria sp.	–	–	–	–	–	u
Emarginula sp.	–	–	–	–	–	u
Solarium sp.	–	–	–	–	–	u
Lamellibranchiata.						
Anomia papyracea, *d'Orb.*	u	–	–	–	–	–
Arca sp.	–	–	–	–	–	y x
Aucellina gryphæoides, *Sow.*	–	–	–	–	–	u
Avicula filata? *Eth.*	–	–	–	–	–	l
Exogyra conica, *Sow.*	–	–	–	–	u	–
Inoceramus latus, *d'Orb*, non *Mant.*	u	u	u	–	–	c y l u b
,, striatus, *Sow.*	–	–	–	–	–	u
,, sp.	–	–	–	–	–	Brixton
Lima aspera, *Mant.*	–	–	–	–	–	u
,, elongata, *Sow.*	–	–	–	–	u	u l
,, globosa, *Sow.*	–	–	–	–	–	u
,, ornata, *d'Orb.*	–	–	–	–	–	u
Ostrea frons, *Park.*	–	–	–	–	–	u
,, normaniana, *d'Orb.*	–	–	–	–	u	–
,, vesicularis, *Sow.*	–	–	u	u	–	common
,, vesiculosa, *Sow.*	c	–	–	–	–	–
Pecten Beaveri, *Sow.*	–	–	–	–	–	u x
,, elongatus *Lam*?	u	–	–	–	–	–
,, orbicularis, *Sow.*	u	u	u	u	u	common
,, (Neithea) quinquecostatus, *Sow.*	–	u	u	–	–	–
Pholadomya decussata, *Phil.*	–	–	c	–	–	–
Plicatula inflata, *Sow.*	y u	–	–	y u	u	common
Radiolites Mortoni, *Mant.*	–	–	–	–	–	u
Spondylus sp.	–	–	–	–	–	u
Teredo amphisbæna, *Sow.*	–	–	–	–	–	u
Brachiopoda.						
Kingena lima, *Defr.*	u	–	u	–	c	l
Magas Geinitzi, *Schloenb.*	–	–	–	–	u	u
Rhynchonella grasiana, *d'Orb.*	u	–	–	–	–	x
,, mantelliana, *Sow.*	–	u	–	y u	c y	l u
,, Martini, *Mant.*	u	y	u	c	–	l u
Terebratula biplicata, *Sow.*	c	–	–	c	y	u
,, arcuata, *Roemer*	–	–	–	–	–	u
,, semiglobosa, *Sow.*	–	–	–	–	–	u b
,, squamosa, *Mant.*	–	–	–	–	–	u
Terebratulina triangularis, *Eth.*	-	–	u	–	–	–
,, striata, *Wahl.*	u	c	–	u	–	–
Crustacea.						
Meyeria Willeti, *Woodw.*	–	–	–	–	–	u
Palæocorystes Normanni, *Bell*	–	–	–	–	–	u
Necrocarcinus Woodwardi, *Bell*	–	–	–	–	–	u
Annelida.						
Serpula ilium, *Sow.*	–	–	–	–	–	x
,, umbonata, *Sow.*	–	–	–	c	–	u
Echinodermata.						
Cidaris dissimilis, *Forbes*	u	–	–	–	–	–
Discoidea subuculus, *Klein*	–	–	–	–	–	u
Glyphocyphus radiatus, *Hoen.*	–	–	–	–	–	u
Hemiaster Morrisi, *Forbes*	–	–	–	–	–	u
Holaster subglobosus, *Leske*	–	–	–	u f	–	–
,, trecensis, *Leym.*	–	–	–	–	y	–
,, sp.	–	–	–	–	–	c
Peltastes clathratus, *Ag.*	–	–	–	–	–	u
Pseudodiadema ornatum, *Goldf.*	–	–	–	–	c	–
,, variolare, *Brongn.*	–	–	–	–	–	u
Salenia Clarki, *Forbes*	–	–	–	–	–	u
Actinozoa.						
Micrabacia coronula, *Goldf.*	–	u	u	–	–	–
Onchotrochus serpentinus, *Dunc.*	–	–	–	–	–	x
Smilotrochus?	u	–	–	–	–	–
Spongida.						
Craticularia Fittoni, *Mant.*	c	–	–	–	–	–
Chenendopora sp.	–	–	–	–	–	Brixton
Nelumbia?	–	f	–	–	–	–
Plocoscyphia fenestrata, *T. Smith*	c f	c	–	c	–	–
,, labrosa, *T. Smith*	–	y u	u	–	–	–
,, reticulata, *Hinde*	f	–	–	–	–	u
,, subruta, *Quenst.*	–	–	–	–	–	u
Siphonia sp.	–	c	–	c	c	–
Stauronema Carteri, *Sollas*	–	c	–	–	–	–

The higher beds (zone of *Holaster subglobosus*) seem to contain but few fossils, but Messrs. Griffiths and Brydone inform us that they have obtained the following species:—

Holaster subglobosus.
Terebratulina striata.
Ostrea vesicularis.
Pecten orbicularis.
Teredo amphisbæna.

Mr. Hill obtained *Hol. subglobosus*, *Hol. trecensis* and *Discoidea cylindrica* from this zone, but no fossils have yet been obtained from the Belemnite Marl.

CHAPTER VIII.

THE LOWER CHALK IN SOUTH DORSET

General Description.

It has been stated in the previous chapter that in passing from the eastern to the western part of the Isle of Wight the Lower Chalk decreases in thickness from over 200 to only 161 feet, and, further, that the decrease occurs mainly in the zone of *Ammonites varians*. This thinning of the Lower Chalk continues westward, though not quite so rapidly at first, for in the space between Compton Bay and Ballard cliff, near Swanage, the decrease only amounts to 18 feet, the total thickness at the latter place being about 143 feet. At Worbarrow Bay, however, eleven miles farther west, it has lessened to 92 feet; at Mupe Bay it appears to be 107 feet; at Lulworth Cove the beds seen only measure 58 feet, and though at this locality there seems to have been some crushing and faulting out, yet there is evidence further west that the thickness of the Lower Chalk does not exceed 80 feet, which, however, it seems to maintain to the vicinity of Abbotsbury.

It is also a very noticeable fact that this thinning is accompanied by, and in all probability is owing to, a diminution in the amount of argillaceous matter present. Near Swanage the formation still consists of alternating beds of chalk and marl, though the former preponderates; but at Worbarrow Bay this has ceased to be the case, and there is nothing to be called marl in the lower part of the stage, the only beds of such a nature being in the upper part.

With respect to the base of the Lower Chalk and the plane of separation from the Greensand no mistake can be made. There is an abrupt transition from nodular sandstone to sandy chalk, and the surface of the sandstone is somewhat waterworn and uneven, as if it had been swept by currents. The basement bed of the Chalk has usually been called Chloritic Marl, simply because it contains much glauconite and many phosphatic nodules, and occupies a position that corresponds with that of the Chloritic Marl in the Isle of Wight. But whether it is strictly the equivalent of that bed (*i.e.* of the subzone of *Stauronema Carteri*), is a matter of doubt, for no specimen of that fossil has yet been found in Dorset; moreover, casts of *Scaphites æqualis* are very abundant in the Dorset nodule bed, whereas in the Isle of Wight this species is so rare in the Chloritic Marl that only one or two specimens have been found, though it is common enough in the chalk between 10 and 20 feet above that horizon.

These facts, taken in conjunction with the visible signs of erosion, make it probable that the so-called Chloritic Marl of Dorset is merely the local base of the Chalk, and corresponds to a slightly higher horizon than that characterised by *Stauronema Carteri*. There is a gap, and some beds are missing, either because deposition ceased for a time or because the influx of a strong current destroyed some of the previously-formed deposit. Probably some beds were formed and broken up again, because many of the phosphatic casts in the nodule bed are broken and rolled; others, however, are sharp, and cannot have been transported from a distance. On the whole, it seems improbable that any deposition was in progress during the epoch of the *Stauronema* beds, for, if such had been the case, phosphatised remains of that calcareous sponge would probably have occurred as derived fossils in the existing nodule-bed.

With regard to the upper portion of the stage, which we have hitherto called the zone of *Holaster subglobosus*, we are in Dorset confronted with a zonal difficulty of some importance; for throughout Dorset this species of *Holaster* is common in the zone of *Am.* (*Schloenbachia*) *varians*, and is very rarely found in the higher beds, a distribution the exact reverse of that which prevails in the midland and south-eastern counties.

Thus the species, which forms a good index of the zone elsewhere, would completely mislead a collector in Dorset; but the zone, regarded as so much chalk, remains, and if another local index of it could be found the difficulty would be slight, for we should merely have to say that the zone of "so and so" in Dorset is the equivalent of the zone of *Holaster subglobosus*, in Kent and elsewhere. Unfortunately in Dorset these beds have yielded but a small number of fossils, and none of them have a restricted range. Thus the zone here is marked off rather by negative characters than by the possession of any special fauna. It is not merged into the zone of *Schloenbachia varians*, for the range of that species and of others associated with it is strictly limited, and it may be urged that if the beds in question were more fossiliferous the usual restriction of some of the species would be observable. Still, it is useless to deny that in this case the zonal method fails us; for, in spite of the fact that the beds themselves are well developed and have in the Isle of Purbeck a thickness of from 50 to 104 feet, it has not yet been proved that there is such restriction of species within this thickness as the zonal method teaches us to expect.

Another peculiarity in the Chalk of Dorset is the setting in of a band of hard smooth chalk above the Belemnite Marl. This band is six feet thick in Ballard cliff and thickens westward till it is more than 20 feet in Lulworth Cove. As in other parts of England the Belemnite Marls are succeeded directly by the

Melbourn Rock, we have had some doubt whether this intermediate band should be regarded as belonging to the Lower or to the Middle Chalk. It contains very few fossils, and such as we could find were not of characteristic Lower Chalk species; more recently D. A. Rowe has obtained Middle Chalk species from these beds, and has consequently placed them in the zone of *Rhynch. Cuvieri.*

STRATIGRAPHICAL DETAILS.

In describing the coast sections in this district it will be convenient to give the complete vertical succession at each locality first, and then to indicate the zonal divisions so far as it is possible to do so.

The first section to be noticed is that of Ballard cliff, on the north side of Punfield Cove, near Swanage. Part of the Lower Chalk here was described by Mr. H. G. Fordham in 1876* and very briefly by Dr. Barrois in the same year.† It was measured more carefully by Mr. A. Strahan in 1888.‡ The following account is based on that of Mr. Strahan, with the addition of some details given by Mr. Fordham:—

		ft.	in.
B	Smooth grey marl (Belemnite Marl) - - - - -	5	0
	Alternations of greyish-white chalk and bluish-grey marl—*Am.* [*Acanth.*] *Mantelli* and *Am.* [*Acanth.*] *navicularis*- - - - - - - - - -	84	0
	Similar beds, with two or three layers of greenish phosphatic nodules—*Am.* [*Acanth*]. *navicularis* about	20	0
A	Alternations of bluish shaly marl and harder grey chalk—*Am.* [*Schloenb.*] *varians*, etc. - - - -	22	0
	Hard chalk marl, weathering into rhomboid pieces -	6	0
	Very hard splintery chalk - - - - - -	1	3
	Sandy and glauconitic marl - - - - - - -	0	10
	Glauconitic sandy chalk, with phosphatic nodules and scattered fossils - - - - -	4	0
	About	143	0

Mr. Rhodes was instructed to make a careful search for *Am.* (*Schloenb.*) *varians* in these beds, but he could not find a fragment of one higher than 30 feet above the top of the basement bed, nor was it common anywhere except in that bed. It would appear, therefore, that the zone of *Am. varians* is barely more than 34 feet thick, but when we recollect that its thickness at Compton Bay (omitting the subzone of *Stauronema Carteri*) is only 52 feet the difference is not greater than might be expected. As however we are uncertain whether this is really the upper limit of the zone, we have grouped the beds into bracket A and bracket B.

If the overlying beds with phosphatic nodules do not belong to the *Am. varians* zone they must be grouped with those that represent the zone of *Holaster subglobosus,* which will thus have a thickness of 104 feet, and be thicker than in the Isle of Wight; but, instead of the massive whitish chalk which constitutes the zone in that island, we have here alternating beds of chalk and marl, and the greater thickness may be due to the local increase of argillaceous matter in the Isle of Purbeck. Fossils are scarce in these beds, but *Am.* (*Acanth.*) *navicularis* occurs to within 20 feet of the top.

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* Proc. Geol. Assoc., Vol. iv. p. 506.

† Recherches sur le Terr. Crét. Sup. p. 101.

‡ See Geology of the Isle of Wight, 1889, and Geology of the Isle of Purbeck, p. 167 (1898).

The Belemnite Marl, which is here only five feet thick, increases to 12 feet near Corfe, where it has been extensively quarried and mined for cement-making, and where an unusually large number of fossils reward the labours of Mr. Rhodes (see list at the end of the chapter). The presence of *Scaphites æqualis* and *Plicatula inflata* among them justifies the retention of this zone in the Lower Chalk or Cenomanian stage.

The outcrop of the Lower Chalk reaches the coast again at Flower's Barrow by Worbarrow Bay, where a good clear section is exposed in the cliff. This was measured by Mr. Strahan* and subsequently by Mr. Rhodes when collecting fossils there; they agree closely in total thickness, but as Mr. Rhodes' account gives rather more detail, it is here reproduced :—

		ft.
B	Buff marl (Belemnite band)	6
	Buff blocky chalk with marly partings	about 55
A	Massive grey chalk with siliceous nodules	21
	Massive grey chalk, glauconitic at the base	6
	Sandy glauconitic chalk with scattered phosphatic nodules ("Chloritic Marl")	4
		92

It will be noticed that the zone of *Ammonites varians*, or Group A, has here put on quite a different aspect; it no longer contains layers of chalk marl, but consists entirely of massive chalk, and it contains lumps of grey siliceous stone with cores of black flint, lumps which do not come away freely as flints usually do, but adhere to the surrounding chalk, so that there seems to be a kind of passage from chalk to flint. Such flints occur in this zone throughout the west of Dorset and the adjoining part of Devon. The only fossils found in it at Worbarrow were *Am.* [*Acanth.*] *rotomagensis*, *Pleurotomaria perspectiva ?* and *Ostrea vesicularis*.

The Group B is similar to that in Ballard cliff, except that it is only half as thick, and the total thickness has diminished from 143 to 92 feet.

In Mupe Bay (formerly spelt Mewps) the Lower Chalk occupies a very narrow space, owing to the high dip, which is from 70° to 80°. Mr. Hill examined this section in 1893, and again in 1900, and felt convinced that what had been regarded as "Upper Greensand" was in reality a downward continuation of the sandy basement bed of the Chalk, and on the second visit he obtained fossils which confirmed this opinion. In April, 1901, Mr. Strahan revisited the section, in company with Mr. Hill, and was able to concur in this view, afterwards publishing a note thereon in the *Geological Magazine*, from which the following remarks are taken*:—"The Lower Chalk becomes extremely impure in its lower part, and contains much glauconite; it thus graduates insensibly downwards into a gritty glauconitic sand. The sand contains a few phosphatic casts, more or less worn or corroded, scattered throughout it, but has a well-marked nodule bed, crowded with these casts, at its base; other fossils, with the shell preserved and not filled in with phosphate, occur also throughout the whole bed." The total thickness of very sandy chalk and glauconitic sand is about 15 feet, and it is throughout rather hard. The nodule bed at its base is in contact with a sandy glauconitic clay, which forms part of the Gault, so that the whole of the Upper Greensand is absent at this place.

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* Geology of the Isle of Purbeck, etc., 1898, p. 176.

At the top of the cliff, 200 yards west of the section on the beach, the same bed is again seen, with about the same thickness, but resting on soft Upper Greensand, of which about 40 feet is seen. The question arises as to whether these appearances are caused by faulting or by erosion. Mr. Strahan considers that there is evidence for both, but thinks that the amount of erosion must have been slight, because of the absence of any fragments of chert in the nodule bed. To us, however, this seems a small difficulty, since there is no chert in the Upper Greensand of Worbarrow Bay, though it does occur at Lulworth. We are disposed to think that there was very considerable erosion of the "Greensand" during the formation of the basement bed, and that the phenomena are largely due to erosion, though probably in part also to a fault. We have little doubt that the glauconitic sand which here forms the basement bed of the Chalk has been derived from the Upper Greensand, and that it occupied a trough or channel eroded in that Greensand by current action, though, owing to the co-existence of a fault, we are unable to ascertain to what depth this erosion extended.

Messrs. Hill and Strahan re-measured the Lower Chalk of Mupe Bay during their joint visit in 1901, but report that it is difficult to be sure of the total thickness, because of the broken condition of the chalk and the occurrence of at least one fault, which occurs just below the Belemnite Marl, and appears to have a throw of about 10 feet. Allowing for this, Mr. Hill thinks the thicknesses of the several parts are approximately as follows:—

		ft.
B	Pale bluish-grey marl (Belemnite Marl) - - -	7
	White chalk in regular courses separated by marly bands, about - - - - - - - -	40
	Massive white chalk, becoming greyer below - -	30
A	Massive greyish chalk, containing scattered flinty concretions, and passing into the next - -	15
	Sandy glauconitic chalk, passing down into rough sand, with a layer of phosphatic nodules at base	15
		107

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* Geol. Mag., Dec. iv, Vol. viii. p. 319.

It will be noticed that this total of 107 feet only exceeds the thickness at Worbarrow Bay by just the thickness of the sandy basement bed.

Of the section in Lulworth Cove, Mr. Strahan says that it is less accessible than that of Mupe Bay, "but the marl-bed can be reached without difficulty on the north-west side of the cove." Mr. Strahan evidently assumes, as previous observers have done, that this band of marl, which is about six feet thick, is the Belemnite Marl, but he does not attempt to explain its position, which is little more than 30 feet above the basement-bed. Professor Barrois measured the section in 1875,* and made the thickness of beds between the base of the Chalk to the base of the marl-band from 32 to 35 feet. Mr. W. Hill measured the same space in 1892,† and made it from 30 to 32 feet; but on his last visit in 1901 he noticed that the true Belemnite marls were either cut out by a slip fault or were hidden by talus.

The marl-bed which has hitherto been taken for the subzone of *Actinocamax plenus* is of a yellowish-grey or buff colour, and weathers into thin platy pieces, thus having a different aspect from the bluish-grey Belemnite Marl of Mupe Bay. Mr. Hill therefore came to the conclusion that it was not the Belemnite Marl, but a development of one of the layers of marl which occur throughout the zone of *Holaster subglobosus* in Mupe Bay. The real *Actinocamax* marl is not seen in the cliff, but Mr. Hill noticed a fallen block on the shore, which consisted of marl having the usual local character of that band; and it was probably from such a block that Professor Barrois obtained the specimen of *Act. plenus* which he records as found here. Only a small area is accessible, and neither Mr. Hill nor Mr. Rhodes succeeded in getting fossils except from the basement-bed, but the total thickness of the Lower Chalk is probably from 75 to 78 feet. The following are the details of this section as measured by Mr. Hill:—

	ft.
White chalk in lenticular beds, with partings of greenish marl - - - - - - - - - -	20
Smooth grey marls - - - - - - - -	6
White chalk divided into beds by thin seams of marl -	16
Blocky white chalk with siliceous concretions - - -	12
Glauconitic chalk with phosphatic nodules and some fossils	4
	58

In Durdle Cove the chalk is too much crushed and faulted to be measurable (see p. 419).

At White Nothe the cliff above the Chert Beds shows, according to Mr. Strahan, from 40 to 45 feet of chalk, smooth and white, with some layers of marl, and having three layers of flinty nodules at 6, 12, and 30 feet above the base. The thickness of the glauconitic chalk at the base is about 3 feet, and the dip is about 5° to the east. "The [*Belemnite*] marl-bed rises from the beach 300 yards west of the ledge of Chert Beds and reaches the top of the cliff 280 yards west of Holworth House." In Mr. Strahan's section (Geology of the Isle of Purbeck, Plate ix.) the Lower Chalk is shown as over 100 feet thick, but the Belemnite Marl has been drawn too high up, making the Middle Chalk too thin. A dip of 5° for 300 yards brings in 78 feet, and this is probably about the real thickness of the Lower Chalk.

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* Recherches sur le Terrain Crét. Sup. 1876, p. 93.

† Quart. Journ. Geol. Soc. Vol. lii. p. 109.

The late C. J. A. Meyer kindly communicated the following note:—"At the base of the massive chalk in the cliff-face there is a bed about three feet thick containing green grains and small phosphatic fragments. This rests on a rough bed about six inches thick, full of green grains and nodules, with many fossils (see list on p. 100), resting on a bed of grit which has an eroded and perforated surface."

Inland, along the line of the great Ridgeway fault, there are few exposures of the Lower Chalk, it being for the most part faulted down out of sight.

Professor Barrois found a quarry open near East Chaldon which showed its lower beds and the basement bed; from chalk with siliceous concretions he obtained *Am.* [*Acanth.*] *Mantelli, Scaphites æqualis, Inoceramus striatus,* and *Lima semiornata.*[*]

Higher beds are exposed in a small quarry north of Bincombe church, where the following section was seen by Mr. W. Hill and myself in 1893:—

	ft.
Melbourn Rock (?), rather hard nodular chalk, 4 feet seen	-
Hard smooth chalk in lenticular beds with marly partings	14
Tough grey marl	5¼
Hard white chalk	3
Firm chalk in thick beds, containing siliceous nodules with flint cores	9

In a chalk-pit half a mile west of Little Cheney (east of Bridport) Mr. Strahan saw the following section:—

		ft.	in.
Lower Chalk. 41′ seen.	Hard nodular chalk, partly laminated and partly made of streaky chalk alternating with rough nodular-bands. A few flints in lower part	25	0
	Grey marl or shaly chalk	1	3
	Massive chalk with 1 inch of blue clay at base	9	0
	Sandy white chalk (base not seen)	1	0
	Beds not seen	3	0
	Chloritic Marl (top not seen)	2	6
Upper Greensand—Calcareous grit, seen for		6	0

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[*] Recherches sur le Terr. Crét. Sup., 1876, p. 86.

Of the Chloritic Marl here Mr. Strahan remarks that it contains "rolled brown phosphatic casts of fossils in a matrix of chalky glauconitic marl. At its base the phosphates are especially abundant, and are mixed with vivid green rolled fragments of grit and many dark green or black grains. The surface of the grit below is vivid green, and has been eroded into holes in which the marl rests."

I observed similar relations between the base of the chalk and the top of the Selbornian in a pit on Chilcombe Hill still further west; here also pebbles of the grit occurred in the glauconitic chalk, but there were few phosphatic nodules.

The following lists of fossils, obtained from the different parts of the Lower Chalk at the localities above described, have been drawn up from several sources, (1) from collections made for the Survey by Mr. J. Rhodes, (2) from the lists published by Mr. Fordham and Prof. Barrois, (3) from a list kindly communicated by Mr. C. J. A. Meyer of fossils collected by him from the basement bed at White Nore.

The letters indicate the localities at which the species have been found thus:—

b=Ballard cliff.
c=Pits near Corfe.
w=Worbarrow Bay.
m=Mupe Bay.
l=Lulworth Cove.
r=Ringstead and White Nore.
x=Chaldon (from Museum Catalogue of Cretaceous Fossils and from Barrois' Recherches.)

List of Fossils from the Basement Bed.

	Localities.
Lamna appendiculata, *Ag.*	b
Ammonites [Acanth.] hippocastanum, *Sharpe*	r
,, [,,] Mantelli, *Sow.*	l r x
,, [,,] navicularis, *Mant.*	r
,, [,,] rotomagensis, *Brongn.*	l r x
,, [Haploceras] vectensis, *Sharpe*	l
,, [Schloenb.] varians, *Sow.*	b l m r x
,, [,,] Coupei, *Brongn.*	r x
Baculites baculoides ? *Sow.*	l x
Nautilus sublævigatus, *d'Orb.*	r
,, expansus, *Sow.*	l
,, largilliertianus, *d'Orb.*	r x
Scaphites æqualis, *Sow.*	l r
,, ,, var. obliquus, *Mant.*	b r
Turrilites Bergeri, *Brongn.*	l
,, costatus, *Lam.*	r x
,, Wiesti, *Sharpe*	r
Aporrhais sp.	r
Avellana cassis, *d'Orb.*	l r
Pleurotomaria sp.	r x
Solarium ornatum ? *Sow.*	r
Arca sp.	l
Cardita tenuicosta ? *Sow.*	x
Cardium mailleanum, *d'Orb.*	r
Chama cornucopiæ, *d'Orb.*	x

	Localities
Inoceramus latus, *d'Orb.*	x
„ striatus, *Sow.*	x
Lima semiornata, *d'Orb.*	m
Ostrea canaliculata, *Sow.*	m
„ vesicularis, *Lam.*	b x
Pleuromya sp.	r
Pecten [Neithea] quadricostatus, *Sow.*	b
Septifer lineatus, *Sow.*	x
Unicardium ringmeriense, *Mant.*	x
Crania cenomanensis, *d'Orb.*	r
Kingena lima, *Defr.*	r
Rhynchonella dimidiata, *Sow.*	r
„ lineolata, *Phil.*	b
„ mantelliana, *Sow.*	b
Terebratula arcuata, *Roemer*	l
„ biplicata, *Sow.*	b x
„ obesa, *Sow.*	r
„ ovata, *Sow.*	r
„ squamosa, *Mant.*	x
„ semiglobosa, *Sow.*	b l m x
Terebratella pectita, *Sow.*	r
Catopygus columbarius, *Lam.*	r
Discoidea cylindrica, *Lam.*	r x
„ subuculus, *Klein.*	m r
Galerites castanea, *d'Orb.*	r x
Epiaster sp.	m
Holaster lævis, *de Luc*	r
„ subglobosus, *Ag.*	l m r x
„ suborbicularis ?, *Cott.*	r
„ trecensis, *Leym.*	m r
Pyrina sp.	r
Serpula antiquata, *Sow.*	m
„ vermes, *Sow.*	r

LIST OF FOSSILS FROM THE LOWER CHALK.

——	Zone of Am. varians.	Zone of Holaster subglobosus.	Subzone of Act. plenus.
Enchodus, sp.	—	—	c
Odontaspis, sp.	—	—	c
Ammonites [Acanth.] Mantelli, *Sow.*	b w	b	—
„ „ navicularis, *Mant.*	—	b	—
„ „ rotomagensis, *Brongn.*	b w m l	—	b
„ „ sussexiensis, *Mant.*	r	—	—
„ [Schlœnb.] varians, *Sow.*	b r	—	—
Baculites	—	—	c
Actinocamax plenus. *Blainv.*	—	—	c l
Nautilus elegans ?, *Sow.*	r	b m	—
„ expansus, *Sow.*	—	b	c
Scaphites æqualis, *Sow.*	b w	w	c
Turrilites scheuchzerianus, *Bosc.*	b	—	—
„ sp.	—	—	b
Pleurotomaria perspectiva ?, *Mant.*	w	w	—
Inoceramus Brongniarti ?, *Sow.*	—	—	c
„ cuneiformis ?, *d'Orb.*	b	—	—
„ mytiloides, *Mant.*	b ?	—	—
„ striatus, *Sow.*	r	m	—
„ „ var. with close set ribs	w	—	b m
Lima globosa, *Sow.*	b	—	—
„ elongata, *Sow.*	r	—	—
Ostrea vesicularis, *Lam.*	b w r	b	c
Pecten Beaveri, *Sow.*	b r	—	w
„ orbicularis, *Sow.*	b	—	c
Plicatula pectinoides, *Sow.*	r	b	c
„ „ var. inflata, *Sow.*	r	b	c

LIST OF FOSSILS FROM THE LOWER CHALK—*contd.*

—	Zone of Am. varians.	Zone of Holaster subglobosus.	Subzone of Act. plenus.
Rhynchonella Cuvieri, *d'Orb.*	—	—	c
,, mantelliana, *Sow.*	r	—	—
,, plicatilis, *Sow.*	—	—	b c
Terebratula semiglobosa, *Sow.*	b	—	c
Terebratulina striata, *Wahl.*	—	—	c
Cidaris (plate of)	—	b	—
Discoidea cylindrica, *Lam.*	b	—	—
,, subuculus, *Klein*	—	b	—
Holaster subglobosus, *Ag.*	b r	—	—
,, trecensis, *Leym.*	b	w	—
Ossicles of star-fish	—	—	c
Serpula antiquata, *Sow.*	—	b	—
Micrabacia (? coronula, *Goldf.*)	m	—	—
Craticularia Fittoni, *Mant.*	m	—	—
Plocoscyphia labrosa, *Smith*	m	—	—

CHAPTER IX.

THE LOWER CHALK IN NORTH AND WEST DORSET, SOMERSET, AND PARTS OF DEVON.

In this chapter it will be convenient to describe not only the exposures along the main outcrop of the Lower Chalk through Dorset, but also those in the outliers near Crewkerne, Chard, and Axminster, in the area where the counties of Dorset, Somerset, and Devon meet.

We shall regard North Dorset as extending from Melbury Hill, near Shaftesbury, to Melcombe Bingham, which lies about half-way between Blandford and Cerne Abbas. Along this tract the general strike of the Chalk is from north-east to south-west, while near Melcombe Bingham it changes to an east and west direction. The remaining part of the county will be described under the head of West Dorset; and thirdly, the still more western outliers will be noticed.

1. North Dorset.

In the northern part of the county the Lower Chalk has much the same facies as that of Hampshire and the Isle of Wight, but its thickness rapidly diminishes toward the south-west. From about 180 feet near Shaftesbury it diminishes to about 100 feet at Melcombe Bingham. This diminution appears to result chiefly from the thinning of its lower portion, the Chalk Marl or zone of *Ammonites varians.* This zone can be traced with a normal facies and with the usual fossils as far as the valley of the Stour, but west of that changes take place, and the marly beds either thin out or change laterally into purer chalk. Thus, by Ibberton, Woolland, and the Melcombes the whole division consists of soft chalk, without any hard beds, and the only marl is that which forms the summit of the stage. In this part of the area the lowest beds are soft and mealy, the higher beds are firmer and more blocky, but fossils are rare throughout, and it is really impossible to separate the zones of *Ammonites varians* and *Holaster subglobosus* from one another. I surveyed part of this tract in 1891, and Mr. Hill continued the examination of the more westerly part in 1893.

Zone of Ammonites varians.

An excellent section of the passage beds between the Greensand and the Chalk is exposed in a large quarry on the north side of Melbury Hill, two miles south of Shaftesbury. The passage here is complete, and probably no two observers would divide the beds in exactly the same way, but in 1891 the succession was noted by me as follows:—

		ft.
	Soil	1
Lower Chalk.	1. Greyish marly chalk with a rough hard bed near the top	6
	2. Grey sandy and marly chalk	4½
	3. Firm marly chalk with grains of quartz and glauconite. In one part this was shaly at the base, but it passes into the next	2½
	4. Very sandy glauconitic marl or marly sandstone, drying to a light greenish-grey (many fossils.—*Am.* [*Schloenb.*] *varians*, and *Stauronema Carteri*)	4
Greensand.	5. Rough glauconitic sandstone, darker in tint (for details see Vol. I., p. 160)	4
	6. Soft greenish sandstone, with few fossils	6
		28

Lithologically, one would put the base of the Chalk at the bottom of No. 3, but the bed below still has much marly or chalky matter in the matrix, and contains the usual characteristic fossils of the Chloritic Marl, so that palæontologically it must be included in the Chalk. There is no break between 4 and 5, and it is possible that even the latter should be excluded from the Selbornian, for it contains *Am. Mantelli* and *Turrilites Bechei.*

This quarry has yielded many fossils, and the following were collected here by myself and Mr. Rhodes from the beds numbered 1, 2, 3, 4.

	Beds 1 & 2.	Bed 3.	Bed 4.
Ammonites [Hoplites] curvatus *Mant.*	–	–	x
,, [Acanth.] Mantelli, *Sow.*	x	–	–
,, [,,] navicularis, *Mant.*	–	–	x
,, [Schloenb.] varians, *Sow.*	x	–	x
,, [,,] Coupei, *Brongn.*	x	–	x
Nautilus elegans, *Sow.*	x	–	x
Scaphites æqualis, *Sow.*	–	–	x
Turrilites costatus, *Sow.*	x	–	–
,, scheuchzerianus, *Bosc.*	x	–	–
,, Wiesti, *Sharpe*	–	–	x
Avellana cassis, *d'Orb.*	–	x	x
Aporrhais sp.	–	–	x
Solarium bicarinatum, *Tiessen*	–	–	x
Trochus (casts of two species)	–	–	x
Arca sp.	–	–	x
Avicula sp.	x	–	–
Inoceramus latus, *d'Orb.*	–	–	x
,, mytiloides? *Mant.*	x	–	–
Lima sp. (cf. aspera, *Sow.*)	–	x	–
Ostrea vesicularis, *Lam.*	x	–	–

	Beds 1 and 2.	Bed 3.	Bed 4.
Pecten orbicularis, *Sow.*	–	–	x
„ elongatus, *d'Orb.*	–	–	x
Plicatula inflata, *Sow.*	x	–	x
Spondylus latus, *Sow.*	x	–	–
Trigonia vicaryana, *Lyc.*	–	–	x
Rhynchonella grasiana, *d'Orb.*	–	x	x
„ dimidiata, *Sow.*	x	–	–
Catopygus columbarius, *Lam.*	–	–	x
Discoidea subuculus, *Klein*	–	–	x
Holaster subglobosus, var. altus, *Ag.*	–	–	x
Plocoscyphia sp.	–	–	x
Stauronema Carteri, *Sollas*	–	–	x

There are several exposures round Melbury Hill, which together make up almost a complete section through the Lower Chalk. The lowest 10 or 12 feet is seen above the passage-beds in the quarry described above, and beds which may be regarded as an upward continuation of these are exposed in a small pit by the cottage south-west of the hill. These are :—

	ft.
Soil containing remains of a layer of hard chalk	1½
Grey blocky chalk marl	2½
Course of hard grey chalk	¾
Grey chalk marl, passing down into bluish sandy marl, with conchoidal fracture, coming out in ball-like lumps	10
	14¾

Between these two exposures there is a large quarry on the west side of the hill, a cartway leading to it out of the main road. At the entrance to this cartway the basement beds are seen. At the entrance of the quarry there is soft marly chalk, with 7 or 8 courses of hard greyish chalk, the usual southern type of Chalk Marl. Higher up are massive beds of firm blocky chalk, alternating with layers of soft marly or shaly chalk. Still higher the chalk is entirely blocky, and becomes nearly white, passing, no doubt, into that of the zone of *Holaster subglobosus* (see p. 108).

A quarry at East Compton, about 20 feet deep, shows grey marly chalk in the lower part, with *Am.* [*Schloenb.*] *varians*, and at top whiter chalk, with several beds of hard chalk, one nearly white, but the topmost greyish-white and a foot thick.

A good idea of the whole Lower Chalk succession can be gained from exposures by the lane leading up to Sutton Hill.

The Chalk Marl can also be examined in a quarry at the north-west end of Hambleton Hill, near Child Okeford. The bottom of this is probably about 30 feet above the Chloritic Marl, and the total thickness of the Lower Chalk may be 160 feet. The beds on the east side of the quarry consist of soft blue and grey sandy marls, alternating with courses of hard grey chalk dipping to the south-east at about 7°. On the west side there are similar beds for about 30 feet, succeeded by some 20 feet of massive grey chalk, so that there seems to be a fault striking through the pit, but it is not clear. Many fossils have been obtained here. I found *Am.* [*Schloenb.*] *varians, Scaphites æqualis, Turrilites sp., Baculites sp., Inoceramus latus* d'Orb., *Pecten Beaveri*, and *P. orbicularis ;* and in the collection of the Rev. J. Penny, of Tarrant, are *Am.* [*Acanth.*] *rotomagensis, Nautilus elegans, Pholadomya decussata, Inoceramus cuneiformis, Pleurotomaria sp.*,and another large naticoid Univalve : also a *Ptychodus* tooth.

Similar beds of soft grey marl, alternating with courses of hard grey chalk, are exposed in the railway cutting a mile and a half south-east of Shillington, and here also fossils are common, the following being found in the lowest hard bed :—*Am.* [*Schloenb.*] *varians, Am.* [*Desmoceras*] *planulatus, Scaphites æqualis, Fusus sp., Avicula gryphæoides*, and *Discoidea cylindrica.*

South-west of Shillington, and about a mile west of the rail-cutting, is a quarry, at the entrance to which soft marly beds are seen, but the chalk quarried is massive greyish white chalk. This, therefore, is the top of the Chalk Marl, and there is hardly room for more than 50 feet below down to the Greensand.

The base of the Chalk is just exposed at the top of a sand-pit half a mile south of Okeford Fitzpaine. This section was described in the first volume of this memoir (p. 164) from notes taken in 1891, but Mr. J. Scanes visited this pit in 1901 and found the upper part of the section better exposed. The following account has been compiled from the notes which he has kindly placed at my disposal. The beds exposed are divisible as follows :—

		ft.	in.
B	Chalky glauconitic marl with phosphatised nodules and fossils	1	6
	Bed of nodular concretions closely packed in a matrix of sandy glauconitic chalk	2	0
A	Dark green glauconitic shelly sand, an irregular bed varying from 8 in. to 2 ft. - - average	1	4
	Nodular glauconitic sandstone - - about	2	6
	Dark green glauconitic sand - - - seen for	12	0
	Over	20	0

If this account be compared with that printed in the first volume of this work (p. 164), it will be seen that the bed of nodular concretions is thicker than it seemed to be in 1891, and that it is separable from the Greensand below. Moreover, it appears to be correlative with the "cornstone-bed" of the Maiden Bradley section (see p. 148), which we now regard as the base of the Lower Chalk (or Cenomanian). Consequently, I now place the plane of division between Selbornian and Cenomanian at the base of this bed, the brackets A and B showing the grouping now proposed. It was pointed out (Vol. I, p. 165) that the fauna of the nodule bed was that of the Rye Hill sand; the list there given is here repeated, with the addition of a few species since found by Mr. Scanes, and the omission of *Exogyra conica* and *Terebratella pectita,* which were obtained only from the sand below:—

Ammonites [Schloenb.] varians.
„ [„] Coupei.
„ [Acanth.] Mantelli.
Avicula gryphæoides.
Pecten asper.
„ Galliennei.
„ (Neithea) quadricostatus
Ostrea canaliculata.
Spondylus striatus ?
Venus rotomagensis.
Rhynchonella grasiana.
Catopygus carinatus.
Cottaldia Benettiæ.
Discoidea subuculus.
Holaster lævis.
Salenia petalifera.
Micrabacia coronula.
Siphonia tulipa (? derived)
Porosphæra globularis.

The next exposure is in a large quarry at Belchalwell, the base of which is not many feet above the Greensand, while the Melbourn Rock is visible at the top. The dip is eastward at about 15°, but, even allowing for this, there cannot be more than 140 feet of Lower Chalk here. Nothing like Chalk Marl is seen, the lowest part consisting of greyish marly chalk, rather soft, but blocky and not clearly bedded; this passes up into greyish-white chalk, which dries nearly white. No fossils were seen *in situ,* only a few in a fallen block of hard grey gritty chalk, which was unlike anything seen in the face of the pit.

At Ibberton, 200 yards north of the church, there is a steep bank, which shows in one place a foot or two of grey chalk-marl with bluish mottlings. There can be but very little of this material, for Greensand is exposed in the hollow below the north-west side of the church, and to the south-west is a small pit in blocky chalk at a slightly higher level.

The next section is at Woolland, in a pit on the slope of the hill, about 350 yards south-east of the church, where the following section was seen by Mr. Hill in 1893:—

	ft.
Soil and chalk rubble - - - - - - - - -	1
Whitish blocky chalk, much fractured - - - - -	3
Soft silty and crumbly chalk, with occasional hard lumps; where damp the colour is darkish grey, but it dries to a light grey - - - - - - - - - - - - -	2½
Grey chalk consisting of very hard lumps with soft silty chalk between them, mottled with brown markings; a few fossils	6

The fossils found were *Am.* [*Acanth.*] *rotomagensis ?* (fragment), *Pecten orbicularis, Rhynchonella grasiana,* and *Terebratula biplicata.* The hard lumps may be regarded as the incipient condition of a course of hard grey chalk, like those farther east.

The next section is a pit near Moots Copse, half a mile north of Higher Anstey. Here Mr. Hill saw:—

	ft.
Soil and rubble - - - - - - - -	1
Greyish-white blocky chalk, breaking into loose angular blocks - - - - - - - - - - - - - -	18
Softer silty chalk, containing many lumps of hard chalk ; seen for - - - - - - - - - - - - -	3

Am. [*Acanth.*] *Mantelli* occurred throughout; the lowest bed yielded *Scaphites æqualis, Turrilites sp., Pecten orbicularis, Inoceramus latus,* d'Orb, *Ostrea sp.,* and *Terebratula semiglobosa.* This pit may be 20 feet above the base of the Chalk.

Beyond this point the hard lumps seem to die out, and the lower 20 feet of the chalk consists entirely of soft silty chalk, breaking into blocks, and only occasionally containing seams of still softer laminated chalk. Thus half a mile north of Melcombe Horsey a pit at Melcombe Park Dairy shows about 14 feet of blocky chalk, softer in the lower half, and without any hard lumps. By digging alongside the farm buildings, Mr. Hill found that the same soft chalk continued to the farm gates, close to which the glauconitic basement bed was seen. Sections a little farther west show that the total thickness of the Lower Chalk is here reduced to 100 feet.

Thus in a distance of less than ten miles this division has thinned from 180 to 100 feet. We think that the lowest beds of the Melbury section, *i.e.,* the zone of *Stauronema Carteri* and the lower part of the Chalk Marl, have disappeared entirely, and that the change in the character of the beds is due to lack of the argillaceous material present in ordinary Chalk Marl. Near Anstey the zone of *Ammonites varians* is probably not more than 30 feet thick, and there are decided signs of erosion at its base.

In the Dorchester Museum there are a number of fossils from the Lower Chalk of Stoke Wake (obtained many years ago from quarries now overgrown) and from near Armswell, a hamlet west of Anstey. Most, if not all, of these must have come from the lowest beds (zone of *Am. varians*). The following is a list of them :—

Ammonites [Acanth.] Mantelli, *Sow.*
,, [,,] rotomagensis, *d'Orb.*
,, [,,] sussexiensis, *Mant.*
,, [Schloenb.] varians, *Sow.*
,, [,,] Coupei, *Brongn.*
Scaphites æqualis, *Sow.*
Baculites baculoides ? *d'Orb.*
Turrilites costatus, *Sow.*
Nautilus expansus, *Sow.*
,, deslongchampsianus, *d'Orb.*

Inoceramus latus, *d'Orb.* non [*Mant.*
Lima globosa, *Sow.*
Pecten Beaveri, *Sow.*
,, fissicosta ? *Eth.*
,, orbicularis, *Sow.*
,, (Neithea)5-costatus, *Sow.*
Ostrea vesicularis, *Lam.*
Terebratula semiglobosa, *Sow.*
Terebratulina striata, *Wahl.*
Rhynchonella grasiana, *d'Orb.*

Zone of Holaster Subglobosus.

Under this head we shall mention those sections which expose the uppermost portion of the Lower Chalk. The first of these is the large quarry previously mentioned on the western slope of Melbury Hill, south of Shaftesbury. The highest part of this shows massive greyish-white chalk and three or four feet of grey shaly marl, overlain by Melbourn Rock.

In the roadway east of Sutton Waldron the base of the Melbourn Rock is seen to rest on a soft buff-coloured marl, with hard greyish chalk below, and a few feet lower there is blocky white chalk. There is a small quarry in similar blocky chalk by the side of a parallel road 250 yards north of this.

The next place where this part of the chalk is visible is a quarry about half a mile south-east of Okeford Fitzpaine, west of the Stour. Here the Melbourn Rock is well exposed, and its massive basement bed passes down into whitish chalk, which breaks along the bedding planes and does not contain nodules ; of this there are about 9 inches. Below it is a thin layer of grey marl, resting on blocky greyish white chalk, without definite bedding, of which about 8 feet are exposed. Here, therefore, there seems to be a local absence of the Belemnite Marls.

The quarry at Belchalwell has already been mentioned ; the Melbourn Rock is seen at the top of this, only a thin seam of marl dividing it from the blocky whitish chalk below.

2. West Dorset.

Under this heading will be described the Lower Chalk along the main escarpment from Melcombe Bingham, westward by Buckland Newton, Evershot, and Cheddington, as well as in the country around Cerne, Maiden Newton, and Beaminster. In this district the formation becomes still thinner, varying from 100 to about 60 feet.

As already stated (p. 108), the Chloritic Marl proper has thinned out in North Dorset before reaching Bingham, and there is no longer a passage from Selbornian to Chalk. On the contrary, there is in most places a clearly-marked plane of division between the two formations ; the uppermost bed of the Greensand is a hard greenish glauconitic sandstone, the surface of which is uneven, waterworn, and cracked ; the lumps and sides of the cracks are coated with green matter, and frequently bear small attached Serpulæ and young Oysters. It has evidently been a water-washed surface during a period of non-deposition. On this surface rests a soft glauconitic chalk, the base of which is often a regular nodule-bed full of light brown phosphatic nodules and phosphatised fossils.

This is the bed referred to by Professor Forbes and Mr. Bristow as containing so many specimens of *Scaphites æqualis* and *Galerites castanea*, and also as being evidently the base of the Chalk. Grains of quartz and glauconite are abundant in this basement bed, but rapidly diminish in number above it, the material passing into a pure whitish chalk. The fauna of this nodule-bed is the fauna of the Chalk Marl, and not the special fauna which is found in the *Stauronema* zone of Wiltshire and the Isle of Wight. A large number of species are, of course, common to both ; but in the Dorset nodule-bed certain fossils, such as *Stauronema Carteri* itself, are absent, and others are common which are very rare or absent in the Chloritic Marl, but abound in the Chalk Marl 20 or 30 feet above it, such as *Am.* [*Acanth.*] *rotomagensis, Scaphites æqualis, Baculites baculoides*, and *Turrilites costatus.*

The Chalk above the basal glauconitic stratum is firm, blocky, and greyish-white, but dries nearly white. It is not a chalk marl in a lithological sense, but a nearly pure chalk, that is to say, it contains hardly any argillaceous matter, and only a little fine sand or silt. Fossils are rare, and only a few of the commonest bivalves have been found, so that we are unable to say how much of it is referable to the zone of *Am. varians.* The lower part often contains flints of a peculiar kind; these consist of a thick outer mass of whitish silica or siliceous chalk, with an internal nucleus of black flint; the centre shades into the white envelope and the latter into the surrounding chalk, so that till broken they look like hard lumps of chalk. These flints only occur in the lower 20 or 30 feet. The higher beds are without them, and consist of still whiter and more compact blocky or bedded chalk, which resembles the higher part of the Lower Chalk elsewhere.

Near the top of the Lower Chalk there is generally some thickness of greyish or yellowish marl, usually from 6 to 10 feet of such material; this is the Belemnite Marl or subzone of *Actinocamax plenus*, though that fossil has only been found at one or two places.

A.—The Basement Bed.

In the more eastern part of the district under description, that is, around Melcombe Bingham and Melcombe Horsey, the topmost bed of the Selbornian is a glauconitic sandstone so full of dark brown phosphatic fragments and fossils that it may be termed a phosphatic conglomerate. Upon this rests the nodule-bed which forms the base of the Lower Chalk (zone of *Am. varians*). Where this facies prevails and where exposures are weathered it requires care to collect separately from the two nodule-beds, but where sections are clear there is no difficulty.

The existence of a well developed nodule-bed above the phosphatic conglomerate at these localities was not known to me in 1899, and was not recognised by Mr. Rhodes when he collected there in 1894; consequently I have no doubt that, of the fossils then obtained by him and recorded as from the topmost bed of the Selbornian in the first volume of this Monograph (p. 168 *et. seq.*), some few really came from the basal bed of the chalk, and are wrongly included in list there given. Such probably are *Am.* [*Schloenbachia*] *varians, Am.* [*Schl.*] *Coupei, Turrilites costatus and Cucullæa mailleana.*

Mr. J. Scanes, who visited this district in 1901 and found a good exposure of the junction-beds at Dorsetshire Gap, northwest of Melcombe Horsey, has kindly put the following notes at my disposal:—

		ft.	in.
Lower Chalk.	Glauconitic chalk with scattered bits of brown phosphate	0	9
	Layer of phosphatic nodules and fossils	0	3
Selbornian.	Phosphatic conglomerate, consisting of dark brown phosphatic nodules in a hard, calcareous, sandy matrix	1	0
	Hard calcareous glauconitic sandstone	3	0
	Light grey glauconitic sand	0	6
	Dark green glauconitic sand, seen for	10	0
		15	6

The phosphatic conglomerate contains many fossils such as large *Pecten* [*Neithea*] *quadricostatus*, *Pecten asper*, *Ostrea frons*, and *Rhynchonella dimidiata*, which retain their shells, and others, such as *Am.* [*Hoplites*] *Studeri*, *Turrilites puzosianus*, and *Cucullæa obesa*, which are phosphatic casts.

The overlying nodule-bed contains two kinds of phosphatic nodules; some are greenish and appear to be phosphatised pebbles of calcareous sandstone, others are of the usual light brown, phosphatic, chalky limestone, and among the latter are the following casts of fossils: *Am.* [*Schloenbachia*] *varians*, *Turrilites costatus*, *Tur. Wiesti*, *Cucullæa mailleana*, and *Holaster subglobosus var. altus*; none of which occur in the underlying conglomerate; *Plicatula inflata*, *Rhynchonella mantelliana*, and *Micrabacia coronula* also occur.

At Bookham Farm, two and a half miles north-west of the section above described, is another clear exposure, where about 5 feet of chalk rests on an eroded surface of the phosphatic conglomerate; but here there is no basal nodule-bed, only an inch or so of sandy glauconitic chalk, with a few scattered phosphates and *Am.* [*Schloenbachia*] *varians*, passing up into less sandy chalk, in which I found *Holaster subglobosus* and a few bits of phosphate A similar facies of the basement bed can be seen in the quarry on Dogbury Hill, north of Minterne.

To the southward, however, near Cerne, a thin nodule-bed is again found resting on hard, rough, glauconitic sandstone, the phosphatic conglomerate having thinned out, or having been destroyed by current-erosion before the deposition of the basement bed of the Chalk. The junction can be seen in the bank of the lane north-west of the Abbey Farm. About 2½ feet of the glauconitic chalk are exposed, the upper portion with only a few green grains passing down into greenish glauconitic chalk with a few phosphates and a thin layer of nodules and fossils at the base, resting on an irregular surface of the calcareous sandstone and filling also open cracks in the same. Lumps of sandstone can be obtained, the sides of which are covered with small Serpulæ.

At Batcombe and Evershot there is a still more conspicuous nodule-bed, and many fossils have been obtained from a quarry in Rocks Lane, north-east of Evershot.

Passing down the valley of the Frome, an excellent exposure of the junction of Chalk and Greensand can be seen in quarry in the field north of Chilfrome House, 4 or 5 feet of chalk with the usual layer of phosphatic nodules resting on the sandstone. A similar junction can be studied in two pits at Maiden Newton, one at Tollerford and one by the side of Chilfrome Lane. Both yield many fossils.

Eggardon Hill, four miles south-west of Maiden Newton, is a fine promontory of Chalk overlooking the lower Jurassic plateau to the west. The base of the Chalk Marl, resting on hard calcareous grit, can be seen on the south-western slope of the hill, and exhibits the usual nodule-bed with many fossils, among which a specimen of *Am.* [*Acanthoceras*] *rotomagensis* and one of *Pleurotomaria cassisiana* retaining the shell were found by the Rev. H. S. Solly, of Bridport. The exposure here was described by Mr. Whitaker in 1870,* and he remarks that the glauconitic and quartziferous chalk is only about 2 feet thick; "2 feet up the grains get fewer, and they are lost at about 4 feet."

Passing westward from Maiden Newton, there are small exposures, whence fossils may be obtained, north of Toller Fratrum and south-east of Penny's Toller, or Toller Whelme as it is called on the new Ordnance map.

There is not now any good exposure near Beaminster, except at Cheddington, about two miles northward, where the junction is exposed in a lane about half a mile south of the church. Many fossils now in the Museum at Jermyn Street and labelled Cheddington were probably obtained from this spot.

The following is a list of the fossils which are found at the base of the Lower Chalk in West Dorset; those from Cerne and Maiden Newton were obtained by myself, those from Evershot chiefly by Mr. Whitaker, and those from Eggardon by Mr. Solly. Those marked S are from previous collections for the Geological Survey, and are taken from the published Catalogue of Cretaceous Fossils. Specimens from Chilfrome, Cattistock, Toller Whelme, Wraxall, and Chalmington are included in the Maiden Newton list.

	Cerne Abbas.	Evershot.	Maiden Newton.	Eggardon.	Beaminster.	Cheddington.
Pisces.						
Elasmobranch vertebra - - - - - - -	1	–	–	–	–	–
Cephalopoda.						
Ammonites [Douvilléiceras] euomphalus, *Sharpe* -	–	–	–	S	–	–
„ [Acanthoceras] hippocastanum, *Sow.* -	1	–	3	–	5	–
„ [„] Mantelli, *Sow.* - -	1	2	3	–	5	–
„ [„] navicularis. *Mant.*- -	1	2	3	4	5	6
„ [Desmoceras] planulatus, *Sow.* - -	–	–	3	–	–	–
„ [Acanthoceras] rotomagensis, *Brongn.* -	1	S	–	4	5	–
„ [Schloenbachia] varians, *Sow.* - -	1	2	3	4	5	6
„ [„] Coupei, *Brongn.* - -	1	2	3	4	5	6

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* Quart. Journ. Geol. Soc., Vol. xxvii. p. 96.

	Cerne Abbas.	Evershot.	Maiden Newton.	Eggardon.	Beaminster.	Cheddington.
Baculites baculoides, *Mant.*	1	–	3	4	5	–
Hamites simplex, *d'Orb.*	–	2	–	–	–	–
Heteroceras sp.	1	–	3	4	5	–
Scaphites æqualis, *Sow.*	1	2	3	4	5	6
Turrilites costatus, *Lam.*	1	2	3	4	5	–
„ tuberculatus, *Bosc.*	1	–	3	–	–	–
„ Wiesti, *Sharpe*	1	2	3	4	5	6
Nautilus deslongchampsianus, *d'Orb.*	–	S	–	S	5	–
„ expansus, *Sow.*	1	2	3	4	5	6
„ Fittoni, *Sharpe*	–	2	–	4	–	–
„ largilliertianus, *d'Orb.*	–	2	–	–	–	–
Gasteropoda.						
Avellana cassis, *d'Orb.*	1	2	3	4	5	6
Columbellina sp.	–	–	3	S	–	–
Crepidula sp.	–	–	3	–	5	–
Dentalium sp.	–	–	3	–	–	–
Emarginula Gresslyi, *P. & C.*	–	–	–	–	–	6
Fusus, (cf. bilineatus, *P. & R.*)	1	2	3	–	5	–
Natica vulgaris, *Reuss*	S	–	3	–	–	–
Pleurotomaria cassisiana, *d'Orb.*	–	–	3	4	–	–
„ sp. 1	1	2	3	4	5	6
„ sp. 2	1	2	–	–	5	–
Solarium sp.	–	2	–	–	5	–
Trochus sp.	1	2	3	–	5	–
Turbo rotomagensis?	1	–	3	–	5	–
„ „ sp.	–	–	3	–	–	–
Lamellibranchiata.						
Astarte cyprinoides, *d'Arch.*	–	–	3	–	–	–
Cardita cottaldina, *d'Orb.*	1	–	3	–	–	6
Chama cornucopiæ, *d'Orb.*	–	–	3	–	–	–
Cucullæa mailleana, *d'Orb.*	1	2	3	4	5	6
Cyprina quadrata, *d'Orb.*	–		3	–	–	–
„ sp.	–		3	–	5	–
Exogyra conica, *Sow.*	–	–	3	–	–	–
„ haliotoidea, *Sow.*	–	–	3	–	–	–
Inoceramus latus, *d'Orb.* non *Sow.*	1	2	3	4	5	6
„ striatus, *Sow.*	–	–	–	–	5	6
Isocardia?	–	–	–	–	5	–
Lima semisulcata, *Nilss.*	–	–	3	–	5	–
Modiola Cottæ?, Goldf. (see Septifer lineatus, *Sow*)						
Myoconcha cretacea, *d'Orb.*	–	–	3	4	5	6
Neæra caudata *Nilss* (=Cuspidaria)	–	–	3	–	5	–
Nucula obesa, *d'Orb.*	1	–	–	–	–	–
Opis bicornis? *Gein.*	–	–	3	–	–	–
Ostrea canaliculata, *Sow.*	–	–	3	–	–	–
„ vesicularis, *Lam.*	–	–	3	–	–	–
Pecten sp.	–	–	3	–	–	–
Plicatula inflata, *Sow.*	–	–	–	–	5	–
Pholadidea sp.	–	2	3	–	–	–
Septifer lineatus, *Sow*	1	2	–	–	–	–
Spondylus striatus? *Sow.*	–	2	–	–	–	–
Thracia (Corimya) carinifera, *d'Orb.*	–	2	–	–	–	–
Trigonia sp.	–	–	3	–	–	–
Unicardium ringmeriense, *Mant.*	1	2	3	4	5	6
Venus rotomagensis, *d'Orb.* (with shell)	–	2	3	–	5	–
Brachiopoda.						
Kingena lima, *Defr.*	S	–	–	–	–	–
Rhynchonella grasiana, *d'Orb.*	1	–	–	–	5	–
„ Martini, *Mant.*	S	–	–	–	–	–
Terebratula arcuata, *Roemer*	S	–	–	4	5	–
„ biplicata, *Sow.*	1	2	–	S	–	–
„ semiglobosa, *Sow.*	1	2	3	4	5	6
„ squamosa, *Mant.*	1	2	–	–	5	–
Terebratulina striata, *Wahl.*	1	–	–	–	–	–
Annelida.						
Serpula umbonata, *Sow.*	1	–	–	–	–	–
Echinodermata.						
Discoidea cylindrica, *Lam.*	1	2	3	–	5	6
„ subuculus, *Klein.*	–	–	3	–	5	–
Galerites castanea, *Brongn.*	1	2	3	–	5	–
Hemiaster sp.	1	–	–	–	–	–
Holaster lævis, *Ag.*	–	–	3	–	–	–
„ subglobosus, *Leske* (type)	1	2	3	4	5	6
Peltastes sp.	–	–	–	–	5	–
Salenia petalifera, *Desm.*	S	–	–	–	–	–
Hydrozoa.						
Parkeria sphærica, *Carter*	–	S	–	–	–	–
Spongida.						
Jerea or Siphonia	1	–	–	–	–	–

B. Exposures in the Mass of the Lower Chalk.

In this area it is impossible to indicate the upper limit of the zone of *Ammonites varians,* for fossils are very scarce, and there is very little change in the lithological character of the chalk till the Belemnite Marl is reached. We shall therefore mention the chief exposures in the mass of the Lower Chalk below the Belemnite Marl in geographical order east to west.

There are several old quarries on the slopes of Nordon Hill, north-west of Melcombe Bingham, but most of them are talused, and only two of them are worth noting. One is that already mentioned at Melcombe Park Dairy farmstead (see p. 107).

The same soft chalk overlying the basement bed can be seen in a pit in Conygar copse, south-west of Armswell Farm, and farther west is a larger pit showing higher beds, consisting of blocky whitish chalk.

A large quarry near Miller's Farm, east of Buckland Newton, cuts through nearly the whole of the Lower Chalk, and must be nearly 100 feet deep, but the upper part is difficult to reach. There is a band of greyish marl at the top, and the chalk below for 30 or 40 feet is firm and white. The middle part is talused on the west, but the east side shows a clear inaccessible face, and there is a dip of about 8° across the pit to the N.N.W. Near the bottom is whitish chalk with siliceous concretions or flints, and the top of the Greensand comes out from below it, but the junction was not clear when the quarry was visited in 1893.

The representative of the Chalk Marl is exposed again in a pit on Dogbury Hill, near Minterne, and here it is much greyer than usual, possibly because it is wetter. At the bottom, which is only a few feet above the Greensand, are about 4 feet of soft grey, silty or mealy chalk, with a few small individuals of *Ostrea vesicularis* and *Terebratula semiglobosa,* but no trace of Ammonites. Above this is rather hard greyish chalk in lenticular beds, succeeded by greenish-white chalk without fossils.

Near Hermitage there are two large quarries, one near the east end of Remedy Coppice and another below Telegraph Hill. Both are 60 to 70 feet deep, but the second is the clearest and shows the following beds :—

Alternating beds of marly chalk and hard whitish chalk.
Rather hard white chalk in thick beds.
Firm grey blocky chalk.
Soft yellowish grey mealy chalk (3 feet seen), with a *Lima elongata* and indeterminable fragments of an Ammonite.

Another good section of the Lower Chalk is exposed in a large quarry three quarters of a mile west of Maiden Newton. Combining measurements taken in several parts of the quarry, the section may be given as follows :—

		ft.	in.
Middle Chalk.	Loose nodular chalk	6	0
	Hard nodular chalk with *Inoc. mytiloides* passing down into chalk which is not nodular		9
	Beds of firm but brittle white chalk, separated by thin layers of marl	5	6
Lower Chalk.	Firm grey marly chalk passing down into soft grey marl; *Actinocamax plenus* found near the top	6	0
	Hard blocky greyish chalk, covered by talus for about 30 feet	?30	0
	Greyish white chalk with occasional nodules of flint; quarried and burnt for lime - about	12	0
	Total, about	60	0

No fossils except those above mentioned were found at this quarry. The lines drawn for the boundaries of the Lower and Middle Chalk near Maiden Newton, on the contoured six-inch maps, show that the thickness of the Lower Chalk is from 80 to 90 feet.

From this point westward to Beaminster and Cheddington there are no good exposures of the Lower Chalk. There are many old quarries indicated on the six-inch Ordnance maps, but very few of them have been worked in recent years. Formerly chalk was largely burnt for lime, but either less is now required in country districts or lime made from the Jurassic limestones is found to be better.

One quarry was worked in 1895 by Stintford Lane, north of Beaminster, and showed about 20 feet of the ordinary type of Lower Chalk in Dorset, blocky, white and mealy in the lower part, rather harder above, becoming greyish and marly near the top. There are a few white siliceous nodules or imperfect flints in the blocky part, but of those I broke only one or two had centres of grey flint.

The base of the chalk was seen in the lane 50 or 60 feet below this section, and there was no sign of the Melbourn Rock above it, so the thickness of the Lower Chalk here must be at least 80 or may be nearly 100 feet.

C. The Belemnite Marls.

Returning to the western border of the district, Mr. Reid saw "grey and yellow marl" below the Melbourn Rock in the road across Nordon Hill, near Melcombe Horsey. The top of the Lower Chalk is also exposed in two places south of Bookham, (1) at the top of an old chalk-pit a third of a mile south-east of Bookham Farm, and (2) in the road cutting 300 yards south west of the farm. The latter is the most accessible, and shows:—

	ft.
Hard white and nodular chalk, with marly bands full of nodules (Melbourn Rock) - - - - - -	6
Rather hard, compact and homogeneous yellowish chalk -	2
Belemnite Marl.—Soft grey argillaceous marl - - seen for	6

The yellow chalk is nearly the beginning of the bed mentioned on p. 94 as coming in above the Belemnite Marls of this county. There is a fault through the marls here, so it is difficult to measure their thickness, but there seems more than 6 feet. The beds are dipping west at 5° or 6°.

The same succession will be found in a lane half a mile north of Alton Pancras, but here the yellowish chalk is 3 feet thick.

The next good exposure is in the long quarry on Giant's Hill, near Cerne Abbas. Here below the Melbourn Rock (see p. 115) and 4½ feet of smooth yellowish-grey chalk, there is soft grey Marl, and at the southern end of the quarry about 5 feet of such grey marl were seen in 1893 overlying yellowish weathered chalk, which passed down into nearly white chalk; the latter contains *Holaster trecensis*, but no fossils could be found in the marl.

Near Maiden Newton there are some very anomalous sections at this horizon. One of these, west of the town, has been already mentioned, where the beds above the 6 feet of grey marl seem to form a complete passage from Lower to Middle Chalk.

A small pit by the roadside on the hill south of Tollerford shows about 8 feet of grey marl and marly chalk in lenticular layers overlying firm-bedded white chalk containing *Holaster trecensis*.

Another exposure at Shatcombe limekiln, about 2½ miles south west of Maiden Newton, tallies well with those near Cerne, showing five feet of soft grey marl resting, as usual, on firm blocky whitish chalk.

Between Maiden Newton and the termination of the chalk range near Cheddington only one exposure of the same horizon has been seen; this is in a chalk-pit west of Beckham's Coppice, near Corscombe, and the section here is:—

		ft.
Middle Chalk.	Hard white nodular chalk with *Inoceramus mytiloides* and *Rhynchonella Cuvieri* (? Melbourn Rock) -	2½
	Smooth greyish-white streaky chalk, becoming soft and marly below - - - - - - - - -	4
Lower Chalk.	Grey marl with irregular beds of greyish blocky chalk, weathering whiter, an irregular jointed mass of marl and marly chalk (Belemnite Marl) - - -	8
	Tough blocky massive grey chalk seen below.	

There is no plane of division between any of the beds, but simply a rapid or sudden change from one to the other. The lowest part of the marly chalk contains a variety of *Ostrea vesicularis* common at this horizon in the Midland counties. The pit is so near the base of the chalk that the beds seen have probably slipped.

3. SOMERSET AND PARTS OF DEVON.

Under this head we shall include all the inland tracts which lie to the westward of those already described. In Somerset, south of Crewkerne, are two small outliers of Lower Chalk, and to the westward is a larger outlier, capped by Middle Chalk. West o Chard there is another irregular tract of Chalk, broken by many faults, but stretching southward beyond Chardstock, and northward to the high ground west and north of Combe St. Nicholas.

West of Chardstock there is a small outlier of Chalk near Whitehouse and Brinscombe Farm, and further west is a longer one running north and south through the village of Membury, which is about four miles N.N.W. of Axminster, this outlier being brought in by a fault.

Near Crewkerne the Lower Chalk presents the same features as in West Dorset, and is about 90 feet thick. At Chard it is thinner, probably from 60 to 70 feet, consisting of (1) the basal nodule-bed, which is a fairly hard rock full of fossils and phosphatic nodules; above is (2) glauconitic chalk passing up into white chalk, and finally (3) grey and buff marls. At Membury there seems to be still 50 or 60 feet of Lower Chalk, but though this differs from that of Chard it shows no sign of passing into sandstone, like that to be described in the next chapter.

Crewkerne and Chard.

A good exposure of the lowest part of the Chalk can be seen in the road-cutting west of Warren Hill, about 2½ miles west of Crewkerne. Lying on the surface of the hard calcareous sandstone, which forms the top of the Greensand, is a loose glauconitic marl, full of quartz grains, and containing some phosphatic nodules and fossils; this passes up into soft glauconitic chalk, the quartz and glauconite disappearing about 4 feet from the base, the material then becoming a greyish-white chalk, which dries white, and contains scattered siliceous nodules, some of them having a black flint centre. Of this chalk about 8 feet are seen, and higher beds were formerly quarried to the westward in Holcombe Copse; the total thickness of the Lower Chalk here must be from 80 to 90 feet, for nodular chalk like Melbourn Rock was seen in the cutting on St. Rayn's Hill about 100 feet above the Greensand.

There are two quarries in the white Lower Chalk on Shave Hill south of Crewkerne, one at the south end above Seaborough, and one near the north end of the outlier. Both show featureless and homogeneous white chalk without fossils.

There are many old quarries in the tract between Crewkerne and Chard, but none of them now show anything of special interest.

Near Chard the best section is that of Snowdown Hill quarry, west of town. A view of this is given in Fig. 28; the Selbornian

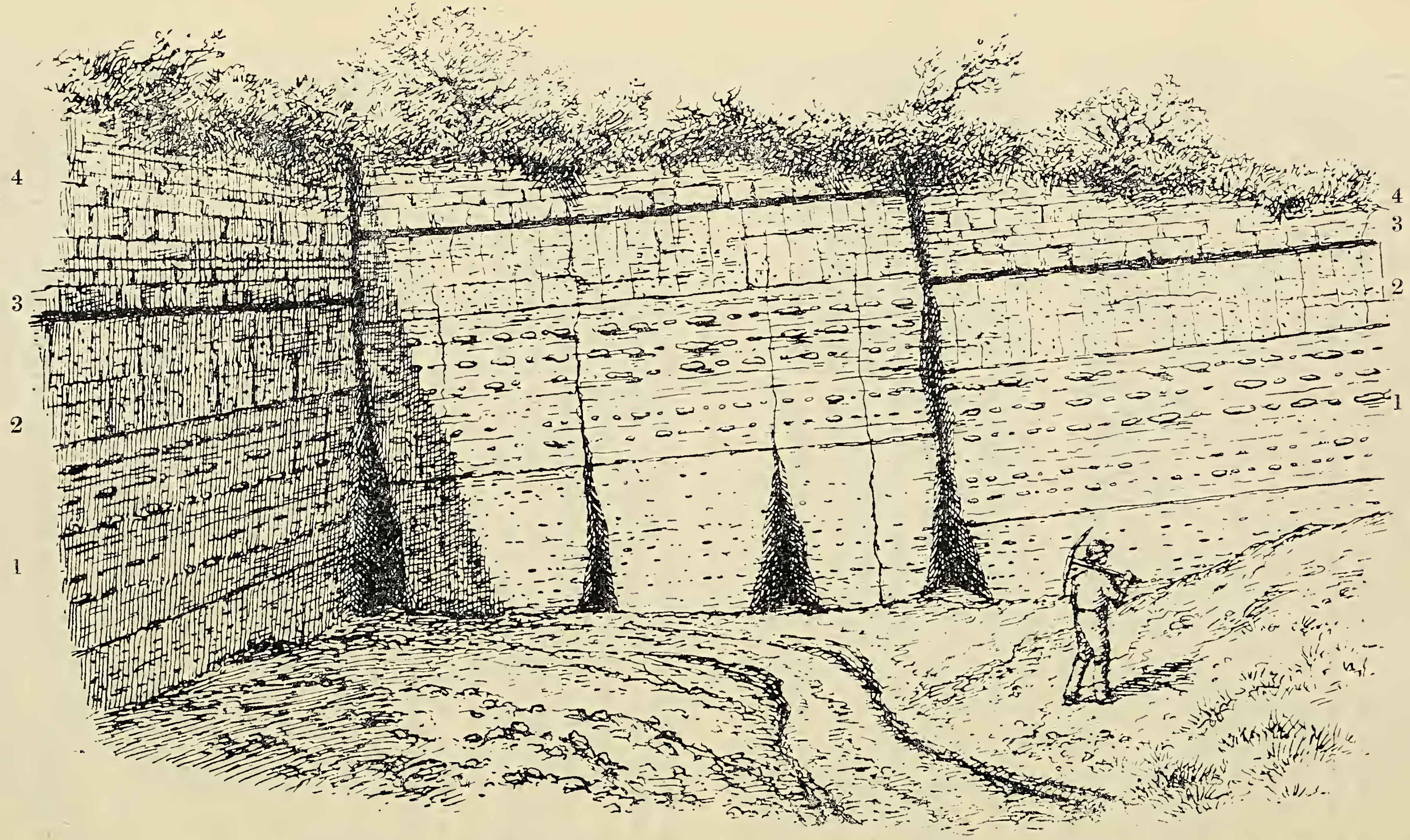

FIG. 28.—View of the Snowdown Quarry, near Chard, as seen in 1892.

4. White Chalk } Lower Chalk.
3. Glauconitic Chalk and nodule bed } Lower Chalk.
2. Calcareous Sandstone } Upper Greensand.
1. Chert-beds } Upper Greensand.

part of the section was noticed in a previous volume, and to the description there given we now add particulars of the Chalk.

The upper part—which is being continually cut back to obtain chalk for lime-making—showed in 1892 about 15 feet; it is a nearly white, very pure chalk, with a few flinty siliceous nodules. About 4½ feet above the Greensand it passes into a somewhat lumpy or nodular glauconitic chalk, of which there is about 18 inches. This passes down into sandy glauconitic chalk full of quartz grains (about 2 feet), and below this is a hard nodular sandy and glauconitic rock, from 9 to 12 inches thick, full of brown phosphatic lumps, and containing many fossils.

This phosphate conglomerate rests directly on the hard calcareous sandstone which forms the summit of the Selbornian stage. There is a complete passage from this basement-bed up into the white chalk. The quartz grains, which are large and abundant in the basal limestone, rapidly lessen in number upwards, and disappear in about 3 feet. The matrix of the basement-bed is a chalky limestone; the brown nodules in it are of various sizes, some small and like phosphatic nodules elsewhere, others large, and these when broken are seen to be only lumps of very hard quartziferous limestone, coated and partly infiltrated with phosphatic matter. These seem to be lumps of a somewhat older bed, broken up and phosphatised, and then embedded in the present nodule-bed.

The fossils also are of two kinds: some are merely brown phosphatic casts, much waterworn, and often covered with small Serpulæ and Polyzoa. These clearly belong to the same category as the small phosphatic nodules. The majority of the fossils, however, including all the larger Ammonites, are well preserved, even the Ammonites retaining the shell, though this often comes away in extracting them from the rock.

This fossiliferous rock has generally been called Chloritic Marl or Chloritic Chalk, but we do not regard it as the equivalent of the Chloritic Marl of Wiltshire and the Isle of Wight, but rather as a condensed representative of the lower part of the Chalk Marl.

An account of the beds above described was written by Mr. J. Wiest, and published in Davidson's "Monograph of the Brachiopoda" (Pal. Soc., 1852), Vol. I, p. 114. The succession is correctly given, and six different beds are distinguished, but three of these really belong to the Upper Greensand, and only the three higher to the Chalk. The basal limestone of the latter is Mr. Wiest's No. III., which he called "the *Scaphites* bed," and described as "a compact accumulation of fossils." The overlying glauconitic chalk (No. 2) he calls the "Chalk Marl or Discoidean stratum," and he specially mentions *Ammonites Mantelli, Discoidea cylindrica,* and *Ananchytes subglobosus* among its fossils. In this he is quite correct, but an inverse order would indicate their relative abundance, *Holaster subglobosus* being particularly common in this glauconitic chalk, and much less so in the "*Scaphites* bed" below.

Mr. Davidson gives a table on p. 115 showing the Brachiopoda found by Mr. Wiest in each of his beds, from which it appears that the same species were obtained from Beds II. and III., except that *Terebratella Menardi* was only found in the latter. The *Rhynchonella Cuvieri* of this list is what he subsequently described as *Rhynch. Wiesti.*

The commonest fossils in the bottom layer or "*Scaphites* bed" are *Am.* [*Schloenbachia*] *varians, Am.* [*Schl.*] *Coupei, Am.* [*Acanthoceras*] *rotomagensis, Am.* [*Acanth.*] *Mantelli, Scaphites æqualis, Turrilites Wiesti, Nautilus expansus, N. lævigatus, Cucullæa mailleana,* and *Galerites castanea.* A complete list of the fossils found at Chard and Chardstock will be found at the end of the chapter.

The quarries at Chardstock, three miles south-west of Chard, are now abandoned and overgrown. There is, however, a small exposure in a quarry half a mile north of Tytherleigh and east of the old quarries.

The higher part of the Lower Chalk was only seen in two places, and in each case it was overlain by grey marl, which may be the Belemnite marl or a band of marl at a lower horizon, like that at Lulworth (see p. 98.)

The first locality was a quarry about two miles W.S.W. of Crewkerne, on the hill south-west of Combe Farm. As seen in 1893, this showed:—

		ft.
Soft crumbling grey marl		6
Blocky chalk with fairly marked bedding, drying nearly white, and seen for		12
Talus hiding beds below	about	12

There is a dip of about 5° to the south, and the surface at the top of the quarry is about 80 feet above the base of the Chalk to the eastward. In the blocky chalk were found *Pecten Beaveri, Pecten orbicularis, Ostrea vesicularis, Inoceramus sp.,* and Sponge remains. No flints were seen.

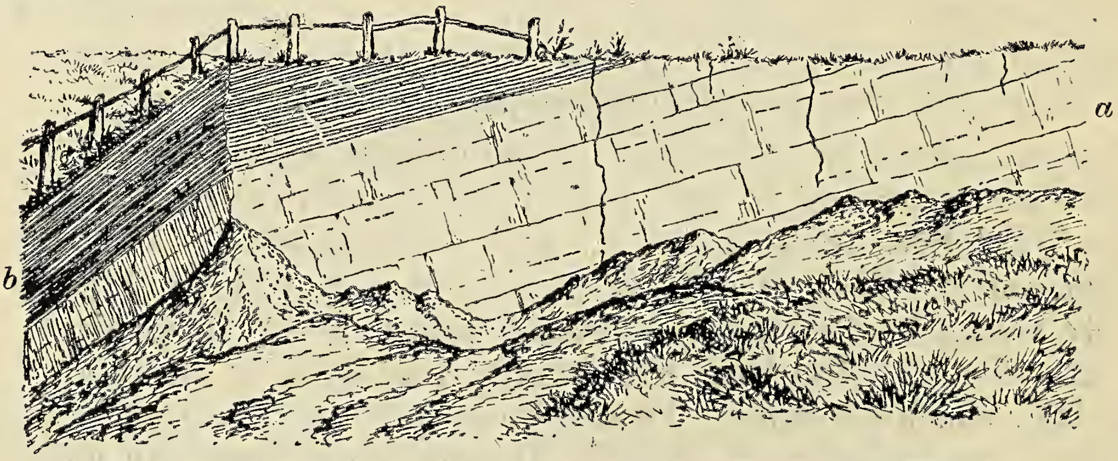

FIG. 29.—Sketch of a Quarry by Combe Wood, near Chard.
a. Whitish chalk. *b.* Soft grey marl.

The only other exposure of this marl met with in the district was in a quarry over two miles north-west of Chard, called Combe Wood Quarry. This is a remarkable section, for the beds dip eastward at about 12°, as shown in Fig. 29.

The white chalk here is not clearly bedded, but jointed, and falls into angular blocks; concretions of white siliceous chalk, some of them with nuclei of black flint, are not uncommon, but have to be looked for in the talus, as they are difficult to see in the pit-face. Of this chalk from 25 to 30 feet are seen, and it dips below greyish-buff marl and marly chalk, of which about 12 feet were visible in 1892. There is a fairly marked plane of division between them, though in places the one seems to pass rapidly into the other. The marl is mostly soft and loose, but it includes lenticular layers of tough, buff-coloured marly chalk. In one spot a mass of grey sandy-feeling chalk was seen in this marl, about 3 feet thick, and resembling soft Totternhoe Stone. The lens showed this to be full of Foraminifera, but no other fossils were found.

The Greensand crops out a short distance west of this quarry, but there were no signs of the base of the Chalk, and the line of junction may be a fault.

Membury.

There are several quarries in the Membury outlier, and as the Middle Chalk comes in as well as the Lower, the locality is an interesting one. The numerous faults make it difficult to estimate thicknesses, but that of the Lower Chalk was judged to be about 50 or 60 feet. At the time of my visit in 1892 the church was being restored, and the chalk thrown out from the foundations was a peculiar soft grey granular chalk. This is about 50 feet below the level of an exposure of Melbourn Rock in the lane to the west.

North of the village there is a series of old chalk quarries; the first of these by the lane leading to Furley is in Middle Chalk, but all the others appear to be in Lower Chalk, and one of them showed the following beds in descending order, below the hedge on the north side:—

	ft.
Hard rough lumpy chalk - - - - - - - - -	?15
Blocky chalk - - - - - - - - - - -	4
Bank with rough lumpy chalk exposed at intervals - about	12
Softer chalk with a layer of rough lumpy chalk - - -	4
White chalk, rather hard, weathering into small brick-shaped pieces - - - - - - - - - - - - -	3

Another pit to the north-west, and nearer Furley, seems to continue the descending section thus:—

	ft.
White chalk, weathering into brick-shaped pieces - - - -	8
Greyish-bedded chalk, soft and silty, with irregular layers of hard lumpy chalk at intervals of 12 to 18 inches - - -	12

The floor of this pit is only a few feet above the base of the Chalk, for glauconitic chalk was seen at the entrance gate.

If this succession is correctly interpreted, there is here about 60 feet of Lower Chalk, and it is of a very different character from that near Chard. Ten or eleven feet of white chalk remain, but both above and below this the chalk is less white, and contains layers of rough lumpy chalk, quite unlike anything to the eastward. Fossils are very scarce, but at the pit near Furley Mr. Rhodes found a small smooth *Avicula* very abundant in the soft white chalk, and also some specimens of an *Inoceramus* resembling *mytiloides.*

In the old quarry, less than a quarter of a mile to the north, the basement bed is exposed, and consists of a hard glauconitic and quartziferous rock, like that near Chard.

The following is a list of the fossils which have been obtained from the basement-bed at Chard and Chardstock, so far as they are at present known. Those with an asterisk were also found in a pit north of Furley by Mr. Rhodes:—

Cephalopoda.

Am. [Acanthoceras] cenomanensis, *d'Arch.*
,, ,, hippocastanum, *Sow.*
* ,, ,, mantelli, *Sow.*
* ,, ,, navicularis, *Mant.*
,, ,, rotomagensis, *Brongn.*
,, [Desmoceras] planulatus, *Sow.*
,, [Hoplites] Bunburyanus, *Sharpe*
,, ,, curvatus, *Mant.*
,, ,, falcatus, *Mant.*
,, ,, ramsayanus, *Sharpe*
,, ,, Salteri, *Sharpe*
,, [Pachydiscus] Wiesti, *Sharpe*
,, [Placenticeras] obtectus, *Sharpe*
[Schloenbachia] Coupei, *Brongn*
,, ,, varians, *Sow.*
Anisoceras armatus, *Sow.*
*Baculites baculoides, *d'Orb.*
*Scaphites æqualis, *Sow.*
Turrilites Bergeri, *Brongn.*
,, costatus, *Lam.*
,, Morrisi, *Sharpe*
,, tuberculatus, *Bosc.*
* ,, Wiesti, *Sharpe*
Nautilus deslongchampsianus, *d'Orb.*
,, elegans, *Sow.*
* ,, expansus, *Sow.*
,, Fittoni, *Sharpe*
,, fleuriausianus, *d'Orb.*
,, largilliertianus, *d'Orb.*
,, sublævigatus, *d'Orb.*
,, undulatus, *Sow.*

Gasteropoda.

Aporrhais sp.
*Avellana cassis, *d'Orb.*
Columbellina sp.
Cerithium sp.
Dentalium sp.
Emarginula sp.
Natica sp.
Pleurotomaria cassisiana, *d'Orb.*
,, mailleana, *d'Orb.*
,, perspectiva, *Mant.*
,, sp. (several)
Solarium ?
Turbo rotomagensis, *d'Orb.*
* ,, sp.
Turritella sp.

Lamellibranchiata.

Arca passyana, *d'Orb.*
Cardita cottaldina, *d'Orb.*
Chama cornucopiæ, *d'Orb.*
Corbis rotundata, *d'Orb.*
,, new sp.
Corimya (see Thracia.)
Cucullæa mailleana, *d'Orb.*
Cyprina quadrata, *d Orb.*
*Exogyra conica, *Sow.*
Inoceramus latus, *d'Orb.*, non *Mant.*
,, striatus, *Sow.*
Isoarca obesa, *d'Orb.*
Lima globosa, *Sow.*
,, intermedia ? *d'Orb.*
* ,, ornata, *d'Orb.*
,, semisulcata, *Sow.*
Lithodomus rugosus, *d'Orb.*
Myoconcha cretacea, *d'Orb.*
Opis bicornis ? *Gein.*
Ostrea vesicularis, *Lam.*
Pecten asper, *Lam.*
* ,, Galliennei ? *d Orb.*
,, [Neithea] 5-costatus, *Sow.*
Plicatula inflata, *Sow.*
*Septifer lineatus, *Sow.* (= Modiola.)
Thracia carinifera, *d'Orb.*

Lamellibranchiata.

Trigonia affinis, *Sow.*
,, crenulifera, *Lyc.*
,, Meyeri, *Lyc.*
,, vicaryana, *Lyc.*
Unicardium ringmeriense, *Mant.*
Venus rotomagensis, *d'Orb.*

Brachiopoda.

*Rhynchonella dimidiata, *Sow.*
,, grasiana, *d'Orb.*
,, Wiesti, *Dav.*
Terebratula arcuata, *Roem.*
* ,, biplicata, *Sow.*
,, semiglobosa, *Sow.*
,, squamosa, *Mant.*
Trigonosemus incertus, *Dav.*

Echinodermata.

Catopygus columbarius, *Lam.*
Discoidea cylindrica, *Lam.*
* ,, subuculus, *Klein*
*Galerites castanea, *Brongn.*
Echinocyphus difficilis, *Ag.*
Holaster lævis, *de Luc*
,, subglobosus, *Leske.*
* ,, ,, var. altus, *Ag.*
Pedinopsis Wiesti, *Wright*
Pseudodiadema ornatum, *Goldf.*
,, variolare, *Brongn.*
,, Rhodani, *Ag.*
Pyrina ovulum, *Lam.*
,, Desmoulinsi, *d'Arch.*
Salenia petalifera, *Desm.*

CHAPTER X.

THE ARENACEOUS BEDS (ZONE OF AMMONITES MANTELLI) IN DEVON.

General Description.

The distance from the outlier of Lower Chalk at Membury to the Bindon Cliffs, near Axmouth, is a little over 8 miles, and from Membury westward to Wilmington is about 4½ miles, yet within these intervals a remarkable stratigraphical change takes place. The Lower Chalk (as chalk) entirely disappears, and in its place there is a variable thickness of calcareous sandstone, overlain by a bed of compact quartziferous limestone. It is unfortunate that no outlier has been found within the intermediate spaces to help us in understanding the precise manner in which the chalky facies disappeared or passed into the sandy facies.

The arenaceous beds are exposed in the coast sections from Lyme Regis nearly as far as Sidmouth, but inland the only good exposures are in the outlier at Wilmington, which was described in 1898.*

These beds appear to represent a part of the Chalk Marl, but as they are neither chalk nor marl, and as *Am.*[*Acanth.*] *Mantelli* is one of the most common and characteristic fossils in them, it is better to speak of them as the zone of *Am. Mantelli*. This appellation is the more appropriate inasmuch as the lower part of the Cenomanian in the west of France has been described by M. Bizet as the "craie glauconieuse à *Am. Mantelli*," and the fauna of the Devonshire beds corresponds very closely to that found in the French zone of *Am. Mantelli*.

These arenaceous beds are the "Chalk with quartz grains" of Sir H. De la Beche,† but the first adequate description of them was that by the late C. J. A. Meyer in 1874,‡ and in his tabular view of the Beer Head section they are numbered as Beds 10, 11, 12. He made a large collection of fossils, keeping those from each of his beds separate, so that they form a valuable record. From the data thus obtained he saw that these beds contained a different fauna from that of the Upper Greensand below, and were every where clearly separable from it; but he also perceived that this fauna included most of the so-called Warminster fossils, and as he then considered the Warminster Greensand to be the equivalent of the Chloritic Marl of the Isle of Wight, he correlated the three sets of beds with one another.

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*Quart. Journ. Geol. Soc., Vol. liv. p. 239.

†Trans. Geol. Soc., Ser. 2, Vol. ii., p. 110, and Report on the Geology of Cornwall, Devon, and West Somerset, p. 237.

‡Quart. Journ. Geol. Soc., Vol. xxx. p. 369.

The coast-sections were examined by the present writer in 1894, and the exposures of the zone of *Ammonites Mantelli* at Pinhay, Whitecliff, Beer Head, and Hooken cliffs were described in some detail in 1896.* In this paper it was pointed out that there was a strong Chalk-Marl element in the fauna, and also that a very large proportion of the species (132 out of 185) occur in the Cenomanian of Western France. It should also be mentioned that Mr. Meyer revisited the sections with one of the writers, and concurred in his conclusions.

In both these papers certain points were left undiscussed. Mr. Meyer's beds, 10, 11, 12, were simply regarded as corresponding to the "lower part of the Lower Chalk," *i.e.*, to the whole or a part of the Chalk Marl. Nothing was said as to the possibility of their including the true Chloritic Marl or subzone of *Stauronema Carteri*; nor was the relation of these beds to the Lower Chalk of Chard and Dorset dealt with, except that mention was made of the occurrence of a similar fauna at the base of this chalk. These two points may now be discussed.

First, with regard to the representation of the Chloritic Marl or subzone of *Stauronema Carteri*. We have seen that it does not occur in Dorset, and we have expressed the opinion (p. 107) that some of the Chalk Marl is also absent in that county. We might therefore expect that there was a similar hiatus in Devon, and so far as the Chard and Membury districts are concerned there probably is; but it is difficult to believe that the quartziferous beds of the *Ammonites Mantelli* zone passed northward and eastward into such pure calcareous chalk as exists at those places. It seems more probable that the arenaceous beds are older than the chalky beds, and even in part older than the phosphatic conglomerate which there lies at the base of the Chalk.

There is, then, no *a priori* reason why some part of Mr. Meyer's Bed 10 should not represent the subzone of *Stauronema Carteri*. This bed contains many sponges, but though careful search has been made for *Stauronema*, not a fragment has yet been found, either in that or the overlying beds. *Turrilites Morrisi*, which is characteristic of the Chloritic Marl in the Isle of Wight, has been found by Mr. Meyer in Bed 12, but not in the lower beds. The fauna contains many species which do not occur in the Chalk Marl, and some of these do occur in the Chloritic Marl and in the still older Warminster Greensand, but this older aspect of the fauna is to be accounted for by the arenaceous character of the deposit and its obviously shallow water origin.

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* See "The Delimitation of the Cenomanian." By A. J. Jukes-Browne and W. Hill. Quart. Journ. Geol. Soc., Vol. lii. p. 99.

Coming next to the question of whether the zone of *Ammonites Mantelli* may be considered to represent the whole of the zone of *Ammonites varians*, we certainly think it more likely that it only represents a part. Taking the development of the latter zone in the Isle of Wight as a standard of comparison, we doubt whether the Devonshire zone of *Am. Mantelli* represents more than the lower 40 or 50 feet of it. We suspect that the plane of separation between the beds numbered 12 and 13 by Mr. Meyer is a hiatus equivalent in time to the formation of three parts of the Lower Chalk of the Isle of Wight and to most if not all of the Lower Chalk of Chard and West Dorset. There is, however, a possibility that Bed 13 may represent the subzone of *Actinocamax plenus*, and this will be discussed later on.

In respect of thickness the zone of *Ammonites Mantelli* varies very greatly; it is greatest at Wilmington, where it is probably over 40 feet thick, and south of this, in Hooken Cliff, it is 24 feet thick, but thins away rapidly both to the east and to the west along the coast, being often only two or three feet thick, and at one place (Charton cliff) it seems to be absent altogether.

A complete list of the fossils which have been found in the zone of *Am. Mantelli* along the coast will be found in a separate column of the General List in Volume III. The fullness of this list is largely due to the labours of Mr. Meyer, who has visited the coast many times for the purpose of collecting from these beds. Collections were also made by myself and by Mr. Rhodes for the Geological Survey.

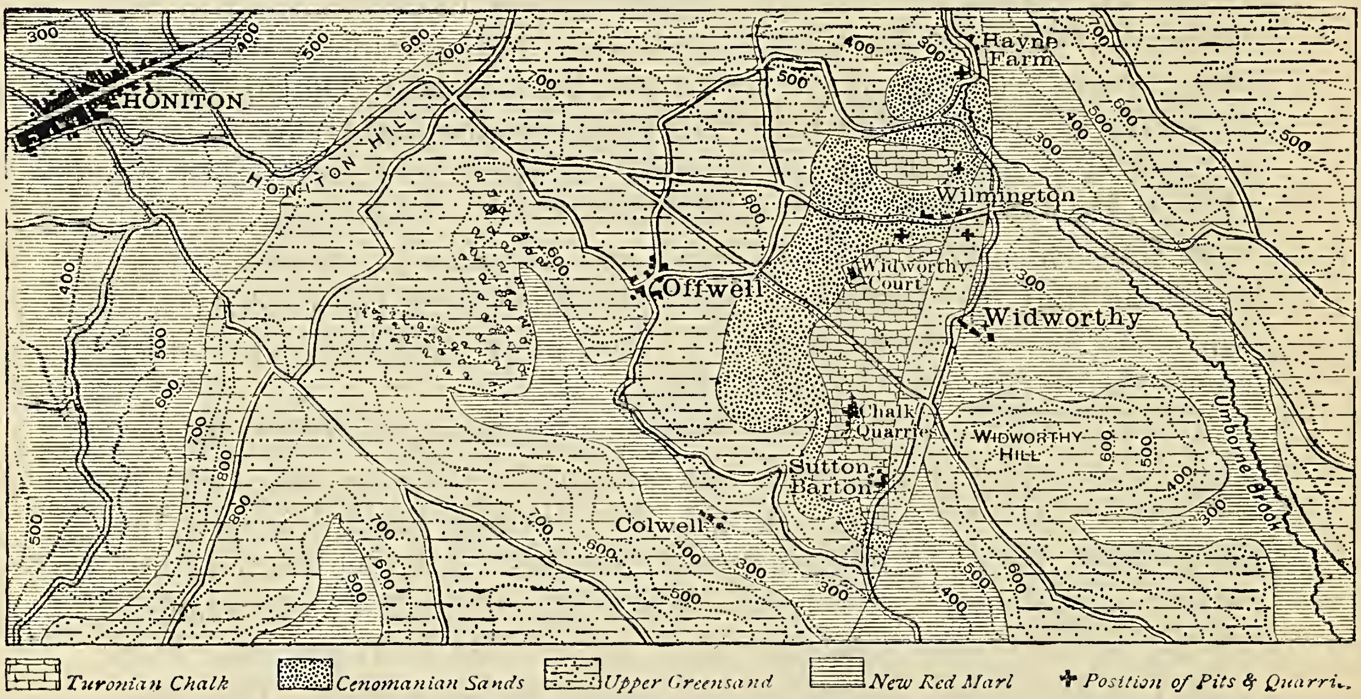

FIG. 30.—Map of the country near Honiton and Wilmington. From Quart. Journ. Geol. Soc., Vol. liv. p. 240. Scale one inch to a mile.

THE WILMINGTON OUTLIER.

The occurrence of hard calcareous sandstone, locally known as "grizzle," was mentioned by Dr. Fitton in his well-known Memoir, and in the following terms:—"In a large pit or quarry at the bottom of the chalk, near Sutton and Widworthy, a stone, called *Grizzle* by the quarrymen, is dug in the situation of the firestone. The beds are altogether about 5 feet in thickness. It contains green particles, and does not burn to lime. Among its fossils is *Catillus Cuvieri.*"* The position of this quarry is shown on the map, Fig. 30 ; the greater part of it is overgrown, but a weathered exposure of the grizzle can still be seen. The fossil mentioned by Fitton is doubtless *Inoceramus striatus*, good specimens of which can be obtained from the exposures now open at Wilmington, which lies to the north of the old Sutton quarries. (see Fig. 30.)

At Wilmington there are two sand-pits opened in the zone of *Ammonites Mantelli*, for though the rock is a hard calcareous grit when covered by some thickness of chalk, it is otherwise where it crops out to the surface, being so decalcified and decomposed that most of it can be easily removed by pick and shovel. The coarse sand so obtained is valued for rough-casting, and for other purposes.

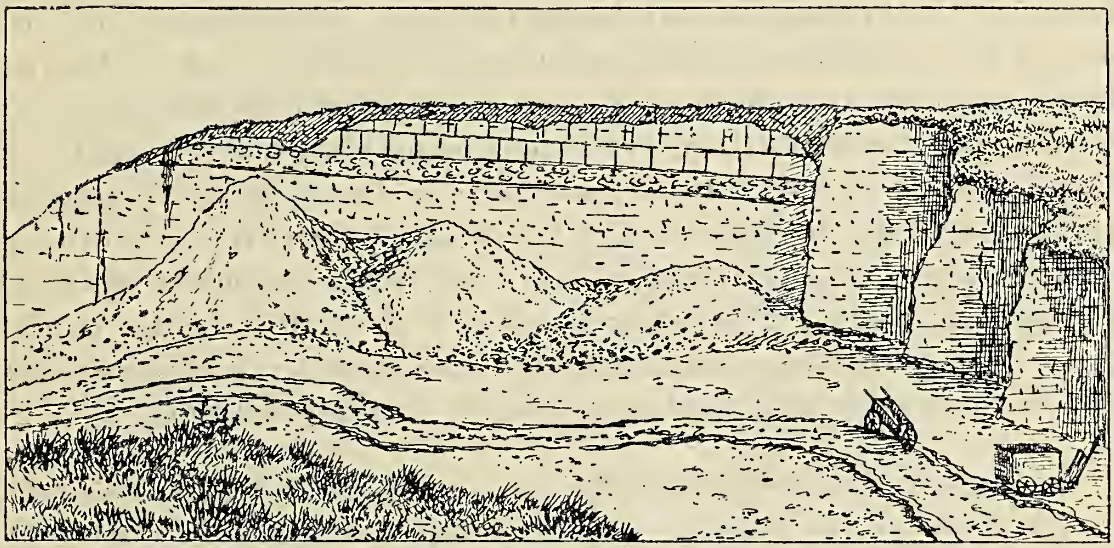

FIG 31.—Sketch of the Quarry north-east of Wilmington.

The pit in a field to the north-east of Wilmington, near the lane to Hayne Farm, shows the junction of the calcareous sandstone with the overlying Middle Chalk, and the following succession was observed in 1897 :—

			ft.	in.
		Vegetable soil and flints.		
Middle Chalk.	5.	Soft bedded white chalk, up to - - - - -	2	6
	4.	Rubbly glauconitic chalk with scattered quartz grains, and a layer of very hard chalk with green-coated nodules at the top, *Inoc. mytiloides* - -	2	6
	3.	Soft glauconitic marly chalk - - - - - -	0	9
Zone of *Am. Mantelli.*	2.	Hard glauconitic and quartziferous limestone, with a worn and phosphatised surface at top, but the base not well marked ; some fossils ; about -	2	0
	1.	Rough yellowish calcareous sandstone with many fossils, weathering into sand with lumps and blocks of sandstone - - - - - - -	6	0

The above measurement was taken on the downthrow side of the fault, shown in Figure 31. On the upthrow side the rough upper part of the sandstone lay just below the soil, so that the throw of the fault cannot be more than 9 or 10 feet.

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* Trans. Geol. Soc., Ser. 2, Vol. iv. p. 234, 1836.

The plane of division between Nos. 2 and 3 is strongly marked the surface of the limestone (2) being phosphatised for a depth of 18 to 28 m.m. ($\frac{1}{2}$ to $\frac{3}{4}$ inch), and in this crust are embedded broken phosphatic casts of fossils, while even the small *Serpulæ* on its surface are phosphatised. This quartziferous limestone passes down into the calcareous sandstone, but the change is rapid, and several fossils occur in the upper bed which are absent or rare below. There are 5 or 6 feet of the rough lumpy sandstone, and this passes down into hard calcareous sand without lumps, but a layer of siliceous concretions is seen on the north side, where about 18 feet of hard decalcified sand has been dug.

The other quarry is on the south side of the road at the western end of Wilmington. The face of this quarry is over 30 feet deep, but does not show the base of the calcareous sand. In the soil at the top are loose lumps of the quartziferous sandstone and large blocks of hard calcareous sandstone (*grizzle*); below these are 3 or 4 feet of soft sandstone, with harder lumpy portions, and in this part fossils are very abundant. The rest of the sand contains only a few fossils, and it cuts with an even face, being chopped out with the broad end of a pick. It is traversed by three layers of siliceous concretions, the highest consisting of large flattish or lenticular masses, white or pink outside, and containing a nucleus of brown chalcedonic chert. The lower layers are of small irregular concretions. They contain sponge spicules, and seem to be sponges more or less filled with sand and cemented by chalcedonic silica.

Wishing, if possible, to find the base of this sand, I had a hole dug in the floor of the quarry, but at a depth of about 12 inches the workman reached a hard rocky sandstone, with large sand grains and some small pebbles, the whole being indurated and compacted by a hard stalagmitic kind of calcic carbonate. The workmen stated that a hole had been dug in the orchard outside the pit traversing 6 or 7 feet of such rock without reaching its base. The total thickness of this calcareous sandstone seems, therefore, to be about 40 feet.

Pebbles also occur occasionally in the mass of the sand. Most of them consist of rough vein-quartz, and one in my possession measures about $1\frac{1}{2} \times 1\frac{1}{2} \times 1$ inches: another is a flat pebble of a greenish micaceous sandstone $2\frac{1}{2}$ inches long.

LIST OF FOSSILS FROM THE ZONE OF AM. MANTELLI AT WILMINGTON.

Since the publication of my description of these beds I have obtained a large number of fossils from the workmen who dig the sand from the pit south of the village, and am now able to give a much longer list of species. A few of them appear to have come from the remnants of the quartziferous limestone left in the soil, but the majority are certainly from the calcareous sandstone, and all belong to the zone of *Am. Mantelli.*

Pisces.

Lamna appendiculata, *Ag.*
Pycnodont teeth.

Cephalopoda.

Ammonites [Acanth.] Mantelli, *Sow.*
,, [,,] navicularis, *Mant.*
,, [Schloenb.]Coupei, *Brongn.*
,, [,,] varians, *Sow.*
Scaphites æqualis, *Sow.*
Turrilites scheuchzerianus, *Bosc.*
,, costatus, *Lam.*

Gasteropoda.

Avellana cassis, *d'Orb.*
Fusus sp. (large cast).
Natica sp. (large cast).
Pleurotomaria mailleana *d'Orb.*
,, sp. (depressed).

Lamellibranchiata.

Cyprina ligeriensis, *d'Orb.*
,, sp.
Exogyra conica, *Sow.*
,, haliotoidea, *Sow*
Inoceramus striatus, *Sow.*
,, sp. (flatter).
Lima elongata, *Sow.*
,, globosa, *Sow.* var.
,, Reichenbachi, *d'Orb.*
,, semiornata, *d'Orb.*
Modiola ligeriensis, *d'Orb.*
Ostrea diluviana, *Linn.*
,, frons, *Park* ? (=carinata).
,, normaniana, *d'Orb.*
,, vesicularis, *Lam.*
,, vesiculosa, *Sow.*
Pecten asper, *Lam.*
,, hispidus, *Goldf.*
,, orbicularis, *Sow.*
,, puzosianus, *d'Orb.*
,, ,, (var. with fine ribs.)
,, (Neithea) cometa, *d'Orb.*
,, ,, quinquecostata, *Sow.*
Plicatula inflata, *Sow.*
sigillina, *Woodw.*
Septifer lineatus, *Sow.*
Spondylus dutempleanus, *d'Orb.*
,, striatus, *Sow.*
Trigonia crenulifera ? *Lyc.*
,, vicaryana, *Lyc.*

Brachiopoda.

Rhynchonella dimidiata, *Sow.*
,, ,, var. convexa, *Sow.*
,, grasiana, *d'Orb.*
,, mantelliana, *Sow.*
Kingena lima, *Defr.*
Terebratula arcuata, *Roemer*
,, biplicata, *Sow.*
,, ovata, *Sow.*
,, squamosa, *Mant.*
Terebratella pectita, *Mant.*
,, Menardi, *Lam.*
,, oblonga ?, *Sow.*
Terebrirostra lyra, *Sow.*
Terebratulina striata, *Wahl.*

Crustacea.

Eucorystes Carteri ? *McCoy.*
Necrocarcinus Bechei, *Deslong.*
,, Woodwardi, *Bell*
Plagiophthalmus oviformis, *Bell*
Crustacean claw.

Annelida.

Ditrupa deformis, *Lam.*
Serpula annulata, *Reuss*

Echinodermata.

Caratomus cf. faba, *Ag.*
Catopygus columbarius, *Lam.*
Cottaldia Benettiæ, *Koenig.*
Cidaris vesiculosa, *Brongn.* (tests).
Discoidea cylindrica, *Lam.*
,, subuculus, *Klein.*
Echinocyphus difficilis, *Cott.*
Galerites castanea, *Brongn.*
Glyphocyphus radiatus, *Hoen.*
Goniophorus lunulatus, *Ag.*
Hemiaster Morrisi ? *Forbes.*
,, bufo, *d'Orb.*
Holaster lævis, *Ag.*. var. carinata.
,, subglobosus, *Leske.*
,, ,, var. altus, *Ag.*
Peltastes umbrella, *Ag.*
,, clathratus, *Ag.*
Pseudodiadema Benettiæ, *Forbes*
,, Michelini, *Ag.*
,, Normaniæ (young).
,, ornatum ? *Goldf.*
,, variolare, *Brongn.*
,, ,, var. Roissyi, *Desor*
,, sp.
Pygurus lampas, *de la Beche*
Salenia Clarki, *Forbes*
,, Austeni, *Forbes*
,, petalifera, *Desm.*
Pentacrinus sp.

Spongida.

Porosphæra globularis, *Phil.*
,, pileolus Lam.
,, sp.

The Cliff Sections.

A mass of Chalk with the zone of *Ammonites Mantelli* at its base comes in as an isolated tract capping the high ground west of Uplyme and Lyme Regis. The Middle Chalk can be seen here and there near the top of Ware cliffs, but there is no exposure of the Cenomanian till Pinhay is reached.

It can be seen in the cliff west of the mouth of Pinhay (or Clevelands) Combe, but is here very thin, and only a small space of it can be reached. It is visible again at the western end of Pinhay cliffs in a great cleft, where part of the cliff has parted and slipped forward; and also at several points along the front of Whitland's cliff. None of these places, however, form convenient points of study, and the composition of the rock can be examined with much greater facility in the fallen blocks which have descended to the beach.

There are several such blocks on the beach west of Pinhay Bay, near the waterfall. These show about 3 feet of hard glauconitic and quartziferous limestone, the upper and lower parts of which exhibit different characters. The lower bed, which we may call A, is a very hard, compact, shelly limestone, coarser and quartzose in the lower six inches, where the coral-like Bryozoan *Ceriocava ramulosa* is not uncommon; this bed varies from 1 to 2 feet in thickness, and rests on an irregular surface of the hard calcareous sandstone which forms the summit of the Selbornian. The upper bed is a hard, rough, quartziferous limestone with green-coated lumps of more compact stone, and a few brown phosphatic nodules. This bed, which may be called B, contrasts with the other also by containing very few fossils, and the change from one kind of rock to the other is rapid, though they are closely welded together and break as one mass. The upper bed also varies from 1 to 2 feet, being thickest where the other is thinnest.

A little farther west there are some blocks which show a remarkable change the lower bed (A) has disappeared, and only the upper one (B) remains (9 or 10 inches thick) welded on to the top of the Greensand and surmounted by another bed (C) consisting of chalk with many large grains of quartz and glauconite and with many derived phosphatic nodules at the base. This is much less hard than A or B, and is about 9 inches thick.

Mr. C. J. A. Meyer examined these blocks in 1895, and agrees with me in regarding A as the condensed equivalent of the beds which are numbered 10 and 11 in his description of the Beer Head section, B as his No. 12, and C as most probably his No. 13.

Below Whitland's cliff, and not far from Humble Point, are some large blocks in which both A and B are shown, the two together having a thickness of 2 feet, of which only 7 or 8 inches belong to B. At the Point are other large masses, one of which shows A and B with a marked layer of phosphatic nodules at the top welded on to B, but having the chalky material of the overlying bed in the interstices. Of this quartziferous chalk (C) with phosphatic fossils and nodules there is about 6 inches, and it is directly overlain by hard, yellowish, gritty chalk with fossils of Middle Chalk species. The following diagram shows the variation in the thickness of the beds seen in the fallen blocks:—

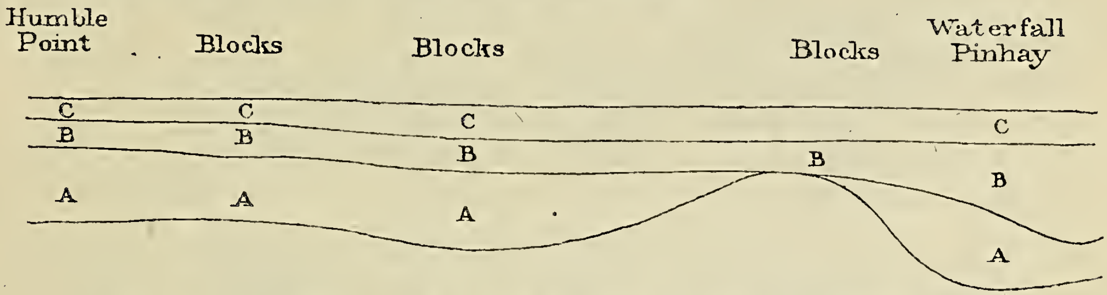

FIG 32. Diagram of the variations in the thickness of the Cenomanian Beds near Pinhay.

Of these three beds, A and B form the zone of *Ammonites Mantelli.* Bed A contains many Sponges and Bryozoa, *Rhynchonella dimidiata* (large), *Catopygus columbarius, Holaster altus, Pecten asper, Trigonia Meyeri, Am.* [*Acanth.*] *Mantelli, Am.* [*Schloen.*] *varians, Am.* [*Placenticeras*] *largilliertianus Turrilites tuberculatus,* and, what is rare in this bed, a specimen of *Scaphites æqualis.* Bed B contains some of the same species with *Galerites castanea, Terebratula rugulosa, Cucullæa mailleana, Columbellina* sp., *Turrilites Morrisi,* and rarely *Scaphites æqualis.*

Bed C contains a large derived fauna consisting of fossils in the state of phosphatic casts. Some of these are common in the beds below, and might have been derived from them; others such as *Scaphites æqualis* and *Avellana cassis,* are rare below but very common in this bed; lastly, there are some which have not been found at all in the older beds. It would appear, therfore, that these phosphatic fossils represent the destruction and riddling of some bed or beds which had previously existed above B. Lastly, this Bed C contains a few fossils which are not phosphatised and belong properly to the bed; the commonest of these is *Rhynchonella Wiesti,* a species which is closely allied to *Rh. Cuvieri,* and with it are *Discoidea cylindrica, Actinocamax plenus* and *Ammonites* [*Douvilleiceras*] *euomphalus.*

The fossil evidence therefore leads us to conclude that there is a great gap between Beds B and C, a conclusion which is confirmed by the waterworn and phosphatised surface of B. But it also compels us to regard C as belonging to the Lower Chalk, to the very highest part indeed, namely, the band of *Actinocamax plenus,* notwithstanding the fact that there is a complete passage from it upward into the Middle Chalk. Physically, indeed, it forms the basement bed of this Middle Chalk, but we prefer to regard that as a local stratigraphical accident, rather than to admit the *Discoidea* and *Act. plenus* as Turonian fossils.

At the extreme end of Whitland's Cliff, above Charton Bay, the Beds A and B have thinned out entirely, so that C rests directly on a phosphatised surface of the Upper Greensand.

The *Am. Mantelli* zone sets in again, however, at Rousedon, and is exposed near the top of the old quarry in the cliff, a quarter of a mile south of the mansion. The section here is as below:—

	ft.	in.
Middle Chalk. Whitish chalk, blocky above, rough and nodular in the lower beds (*Rh. Cuvieri* zone)	15	0
C. Rough glauconitic and quartziferous chalk	0	9
B & A. Glauconitic limestone with phosphatic nodules in the upper part; compact and shelly below, with *Am.* [*Schl.*] *varians*, *Am.* [*Acanth.*] *Mantelli*, etc.	2	0
Upper Greensand	about 37	0

Here Beds A and B form a single course of hard glauconitic limestone with clearly-defined upper and lower surfaces. This limestone can be followed along the Dowlands cliffs till the ground falls away into the valley which separates these cliffs from those of the Bindon landslip. It can be reached at many points in the great cleft of this landslip, but the relations of the beds are somewhat different here; the lower limestone (A and B) is thinner (about 18 to 20 inches only), and the Bed C thickens to about 18 inches, becoming also hard and more clearly separated from the chalk above.

The lower bed is fine grained, compact, and shelly, corresponding chiefly with Mr. Meyer's Bed 11, without any coarse grit at the base to represent his No. 10, and with only a few inches at the top that contain greenish lumps, and seem to represent Bed B (his No. 12). At the base of C there is a layer of phosphatic nodules and fossils, but in the mass of C no fossils except *Rhynchonella Cuvieri*, var. *Wiesti*, and *Galerites castanea* were found, the former being common.

Beyond the landslip valley and at the west end of a fine cliff facing south, the bed is again accessible, and the succession is as follows:—

	ft.	in.
Hard rough nodular chalk (Turonian)	10	0
? C. Very hard gritty limestone, consisting of quartz and glauconite in a chalky cement	0	9
A & B. Hard glauconitic and sandy limestone, with a layer of phosphate nodules at top	1	3
Upper greensand—rough yellowish sandstone	8	0

Here the two glauconitic limestones are thinner than they are 200 yards further east, and there is less separation between them than usual, so that they seem to form one bed about 2 feet thick with a layer of phosphatic nodules about 9 inches from the top. It is, however, only the lower bed which represents the zone of *Ammonites Mantelli.*

Beyond this the chalk retires from the edge of the cliff-slope for a space, but comes in again at Haven Cliff, where the Cenomanian limestone is nearly 2 feet thick, and contains *Pecten asper*, *Rhynchonella dimidiata*, &c.; the usual layer of phosphate nodules occurs above it.

The next section is that of Whitecliff, west of Seaton, but the base of the Chalk in this cliff is only accessible at two points, first, where a fall has left a means of access over a broad talus slope of debris, and, secondly, in the roof of a cave near the point of Beer Harbour. There are, however, many fallen blocks in which the structure of the limestone can be more readily examined.

In the cliff it can be seen that the lower surface of the Cenomanian limestone is a well-marked plane, generally very even and level, but here and there are angular pockets and fissures in the underlying rock, which are filled with material from above. Although this plane of separation is clear, it is not conspicuous, because both beds are so hard and calcified that one does not project beyond the other.

The Cenomanian limestone breaks away in one bed, but examination of the fallen blocks shows that there are really two if not three layers. It seems to be thickest toward the northern end of the cliff, for some blocks below this show a thickness of nearly 4 feet, while at the southern end it is only 2 feet thick. Where thickest pieces of *Ceriocava ramulosa* have been found near the base, showing that Bed 10 of Mr. Meyer's numeration enters into its composition ; the central part is a compact shelly limestone, yellowish-white, with small scattered glauconite grains, but with many quartz grains, both large and small ; it is full of fossils and broken shells. The upper part (Bed 12 or B) is greenish from the number and larger size of the glauconite grains ; it also shows greenish and brownish stains, and contains lumps of partially phosphatised stone, but not so many fossils as the lower part. The microscopic structure of these beds is described in Chapter XXII.

The upper surface of the limestone is a marked plane, and there is nothing to represent C, except nests of glauconitic sand embedded in the base of the overlying Turonian limestone.

The sandy limestone and the overlying hard nodular chalk sink south-westward together below Beer Harbour, and form a ledge which is dry for some distance at low water. They emerge from beneath the pebble beach in the cliffs south of Beer, and the limestone is well exposed for a short distance in a low anticline, which succeeds the synclinal flexure of the harbour. Thence it keeps nearly horizontal for a little distance, but gradually dips southward to the caves (or Hall rocks) north of Pounds Pool.

The section south of Beer is similar to that at Whitecliff, where first seen the Cenomanian limestone is 2½ feet thick, but thins southward rapidly, and on the south side of the anticline, where the cliffs form a projecting point, it is only one foot thick. In the little cove on the south side of this point its thickness is 16 inches, and this increases rather rapidly to 2 feet, and finally to 2½ feet. Attention may here be called to the fact that it is the lower part which varies so much in thickness, the upper course both here and at Whitecliff keeping about a foot, never less than 10 nor more than 18 inches.

In the anticline above mentioned there is at one place a fissure breaking the surface of the Upper Greensand and filled contemporaneously with Cenomanian material.

The next good section is found at Pounds Pool, where another low anticline once more brings the Cenomanian above the level of high tide. Here the two layers or courses become distinct and separate beds, and the succession at the north end of the cove is as follows:—

		ft.
	Base of Turonian.—Hard rough yellowish nodular limestone, with green grains in lower part	1½–2
Cenomanian.	B. Hard glauconitic quartzose limestone with green coated nodules at top and bottom and scattered throughout; base irregular, and piped into bed below - - - - average thickness	1½
	A. Very hard whitish shelly limestone, with less quartz and glauconite than bed above; no phosphates except at very top, but scattered patches of glauconitic sand here and there. Many fossils. Maximum thickness	3
	Selbornian.—Hard rough calcareous grit, with few fossils, passing down into sandstone	6

The plane of division between Cenomanian and Selbornian is well marked, and for the most part even. From the place where the above section was taken both beds thin toward the centre of the anticlinal, where they are out of reach, but seem to be each about 9 inches thick. Viewed from the bay, it is seen that these limestones thicken in each direction from the summit of the anticline, but most rapidly to the northward.

From Pounds Pool southward the two beds of limestone can be followed with the eye through the cliffs, though they are only accessible here and there; their combined thickness varies between 3 and 5 feet, and just before reaching Beer Head measurements taken from a large fallen block gave 20 inches for the upper bed and 3 feet for the lower bed, each having the same characters as at Pounds Pool. A great change then takes place, the mass of the two limestones, with well-marked lower and upper surfaces, can be seen to thicken out rapidly in the cliff which forms the actual headland; and where next accessible at the top of a pile of fallen blocks about 50 yards west of the headland the section is as follows:—

		ft.	in.
	Base of Turonian.—Hard yellowish gritty and glauconitic limestone	2	9
Cenomanian.	B. Hard quartziferous and glauconitic limestone, with green-coated nodules at the top and two layers near the base; weathers to a pitted or honeycombed face. *Holaster subglobosus*, and other fossils	2	6
	A. Hard whitish gritty limestone, with layer of green-coated nodules at top; compact and shelly in upper part with *Pecten asper*, *Holaster altus* *Am.* [*Acanth.*] *Mantelli*, etc.; lower part coarse-grained, with *Ceriocava ramulosa* and other Bryozoa	11 to 12	0
	Selbornian.—Calcareous sandstone of finer grain than the coarse grit above it; upper surface well marked, few fossils	10	0

Holaster subglobosus and *Terebratula arcuata* are common in the upper bed B, but do not occur in A; while *Pecten asper* is common in A, and does not, so far as I could ascertain, occur in Bed B. *Holaster altus* and *Hol. lævis* are also common in A and rare in B.

The lowest 3 or 4 feet of Bed A is a very coarse grit with large quartz grains and some pebbles of vein-quartz and hornstone, but fossils are still abundant in it, the branching forms of *Ceriocava ramulosa* being especially conspicuous. Many of these *Ceriocava* are bored by *Lithodomus*. Single valves of large *Terebratella pectita* and of *Rhynchonella dimidiata* are also not uncommon.

The amount of glauconite in the upper bed seems to vary, the more western fallen blocks showing 2 feet of greenish limestone like that of Whitecliff, with green stains between the nodular lumps and a marked layer of green-coated nodules at the top.

As these beds are followed with the eye above the pebble-beach, which is marked "Little Beach" on the 6-inch map, the lower and coarser part of A is seen to thin out, leaving this bed only about 5 feet thick, while B above keeps about 2 feet.

Where the beds abut against the grass slope of Hooken undercliff this lesser thickness seems to be maintained, but they are not well exposed or easy of access.

Fallen masses on the shore below the landslip show that another sudden thickening takes place; the main mass of the landslip at the "Pinnacles" shows a good, clear, vertical section of these beds on its northern side, and another section can be measured by help of the talus slope down the face of Hooken cliff, a little to the south-east of the Coastguard Station (see Fig. 33). Placing these three sections side by side, we have the following remarkable evidence of local thickening toward the west, as well as of the incoming of a new bed, which is evidently the equivalent of that referred to as C near Lyme Regis.

	Shore.	Pinnacles.	Cliff.
C. Rough gritty greenish glauconitic sand in chalky matrix, with scattered brown phosphates—*Actinocamax plenus* - -	0	4	6
B. Very hard gritty limestone, having a thick layer of brownish green-coated nodules at top, passing down into hard rough nodular whitish gritty limestone, with greenish sand in the interstices—*Holaster subglobosus* - - - - -	4½	5	5½
A. Very hard calcareous grit, with a nodular phosphatised layer at the top, which is planed off to a flat surface; a whitish gritty and shelly fossiliferous limestone with little glauconite, coarse and rough near base, where *Ceriocava ramulosa* occurs; *Pecten asper* and *Holaster lævis* common in upper part - - - -	+12	+16	18
Totals -	+16½	+25	29½

Thus we find that Beds A and B, which are only about 7 feet thick above the centre of Little Beach, have thickened to no less than 23½ feet at Hooken Cliff, with the further addition of 6 feet of glauconitic sand, making a total of nearly 30 feet for the Cenomanian part of this cliff.

With respect to Bed A, the base was not seen on the shore or at the Pinnacles, but in Hooken Cliff it is visible where not obscured by downwash, and, as usual, it rests on a well-marked even surface of the uppermost Selbornian sandstone. There can be no doubt that it is the same as the 11 feet of fossiliferous grit of Beer Headland, nor that it is the " bed 10 " of Mr. Meyer's paper on the Beer Head sections; but it seems to me equally clear that it is only an expansion of the bed which he numbered 11 at Whitecliff, and that the bed which he took to be 10 at Whitecliff is the uppermost calcareous sandstone of the Selbornian stage.

Bed B has changed its character to some extent in thickening out; there is now only one layer of green-coated nodules, and this is at the top; the lower part is quite free from such nodules, and forms a somewhat massive, whitish limestone full of quartz grains with patches and nests of greener, more glauconitic sand. Mr. Meyer has kindly shown me the original section he took at Hooken, and it is the lower half of this bed which he has numbered 11. It is characterised by the abundance of *Holaster subglobosus* of typical form, although this fossil does occur in upper part of the bed, and also in the upper 3 feet of the bed below (A). Mr. Meyer's Bed 12 at Hooken is the upper part of what I have here called B.

Bed C is Mr. Meyer's Bed 13, and his description of it, as seen at Hooken Cliff (Beer Head in his paper), is sufficiently accurate, but I think he was mistaken in identifying it as a definite bed elsewhere. It does not seem to me to exist as a bed even in the slipped masses on the shore below the Pinnacles, but the glauconitic material of it and some of its fossils have been worked up into the base of the Turonian limestone. Its most characteristic fossils are *Actinocamax plenus* and varieties of a *Rhynchonella*, which appears to be the *Rh. Wiesti* of Quenst. A form like *Rh. mantelliana* is also present. There are also a number of derived phosphatic fossils, among which is *Am.* [*Acanthoceras*] *hippocastanum*, though this does not occur in the beds below.

In the upper part of C I found *Galerites subrotundus* (a Turonian species), and there is a complete passage from this bed into the hard nodular Turonian chalk, so that physically it is rather the base of that stage than the top of the Cenomanian.

The group of beds just described can be followed with the eye for several hundred yards to the westward, but the rise of the beds in that direction takes them high up into the cliff, and it is impossible to say how far B and C extend. It is certain, however, that they either thin out or were cut out by contemporaneous erosion, and that much of the overlying chalk also disappears, until finally the soft chalk of the *Terebratulina* zone comes to rest on an eroded surface of the basal part of Bed A.

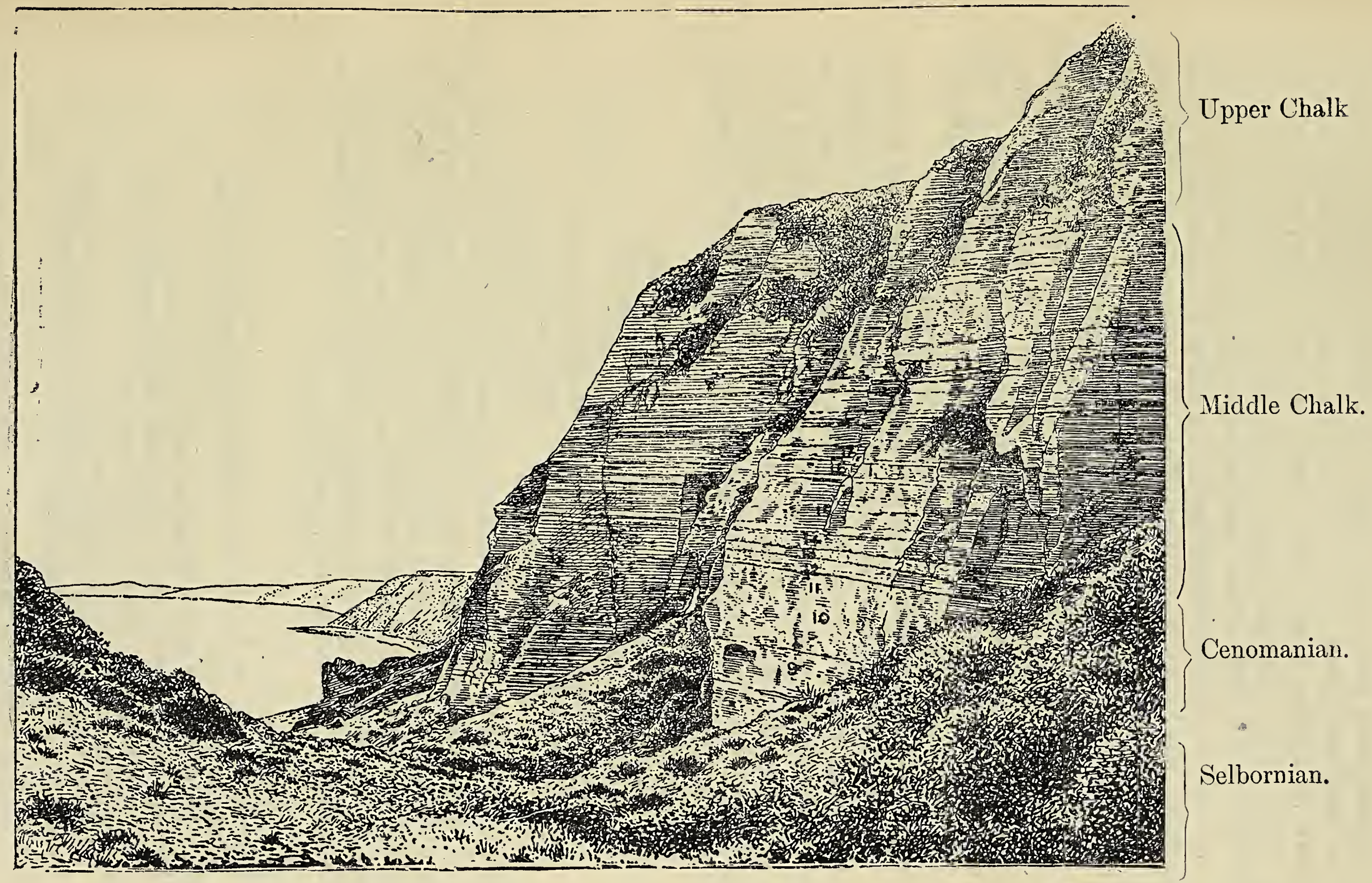

Fig. 33.—View of Hooken Cliff, west of Beer Head, drawn by Mr. H. W. G. Williams, from a photograph in Frith's Series. The numbers on the face of the cliff correspond with the numbers of Mr. Meyer's beds.

The remarkable phenomenon was first noticed by Mr. Whitaker in 1871, but has not been described by any subsequent writer. The actual facts are rather more complicated than is represented in the diagram given by Mr. Whitaker, and it will be more convenient to discuss them when describing the Middle Chalk (see Fig. 77, p. 439). In this place it need only be said that the disappearance of the beds above mentioned, together with the greater part of Bed A, can be ascertained by a careful examination of the large fallen blocks on the undercliff near the boundary line between the parishes of Beer and Branscombe.

There are three of these blocks near the outer footpath, and the two more easterly both show about two feet of coarse fossiliferous grit, in every respect similar to the basal part of A at Beer Head; this grit yields the same Bryozoa and Sponges, and rests on a well marked surface of a massive calcareous sandstone, such as forms everywhere the top of the Upper Greensand.

The third block, which is known as Mitchell's Rock, has come to rest in a more horizontal position, and includes a fair thickness of the overlying chalk. This block shows 3 feet of bed A, with the same characters and many fossils, especially in the upper foot, which is immediately overlain by the soft white chalk of the *Terebratulina* zone. From the fossiliferous grit in this block I obtained the following fossils *:—

Elasmostoma sp.
Tremacystia d'Orbignyi.
Membranipora sp.
Ceriocava ramulosa.
Radiopora (Cellulipora) ornata
Rhynchonella dimidiata.
Pecten acutus ?
„ hispidus.
Lima sp.
Modiola sp. (cast).
Pectunculus sp.
Trigonia vicaryana.

The west end of these cliffs is inaccessible, but, so far as can be judged by looking from the top, the conditions existing at Mitchell's Rock continue to the mouth of the Branscombe valley. There is, however, a small quarry about half a mile east of Branscombe Vicarage, where A appears to be absent, while a thin representative of B is present, the section being as follows:—

	ft.
Soil, with flints - - - - - - - - - -	2
Yellowish loam, with scattered flints and remnants of soft chalk at the base - - - - - - - - - - -	3
Very hard compact white limestone without glauconite -	½
Hard glauconitic limestone, with green-coated nodules and many fossils, *Am.* [*Acanth.*] *Mantelli*, etc. - - - - -	1
Hard calcareous sandstone, rough and full of quartz for about 3 feet, passing down into massive sandstone, which has been quarried for building stone (Selbornian), seen for - -	12

The beds dip eastward at about 3°, and a fallen block exposed the plane of separation between the sandstone and the limestone, showing a layer containing many pebbles of sandstone and many specimens of *Trigonia* (chiefly *T. excentrica*) and some other fossils. This layer is merely the thickness of the pebbles and fossils, and is all that can be regarded as representing the Bed A.

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* The Sponges and Bryozoa were kindly identified by Dr. Hinde.

From all the facts I think we may conclude that the two clearly-marked planes of division which are seen above Beds A and B respectively below the Coastguard Station are really planes of erosion; that both these beds, A and B, were originally deposited over the tract where one or both are now absent, but that this tract was swept by a strong current which at the two epochs indicated by the erosion-planes became strong enough to carry away and destroy some of the material it had previously deposited.

The very thickening of the beds from Beer Head westward suggests that the materials were piled up into a kind of bank or ridge, and that it was the greater part of this ridge which was subsequently destroyed by current action.

Crossing the mouth of the Branscombe valley, the Cenomanian beds are found again at the top of Branscombe cliff, coming in where this reaches a height of 300 feet. For a little distance, however, they are not easily accessible.

In a bluff east of the rock called the Duck and Button there is a section which can be reached by climbing, and in which there seem to be three distinct beds, no doubt corresponding with Mr. Meyer's 10, 11, 12. The succession here is as follows:—

		ft.	in.
Turonian.	Rough nodular chalk, about	6	0
	Hard rocky chalk, with grains of quartz and glauconite, base clearly defined	1	0
Cenomanian.	B. Grey gritty limestone, with a layer of green-coated nodules at top	0	10
	A. 2. Hard shelly and sandy limestone	2	0
	1. Rough fossiliferous grit, base not seen at this exposure, but thickness more than	4	0
Selbornian.	Massive calcareous sandstone, about	10	0

From this place the fossiliferous grit, A1, is seen to thin out rapidly in both directions, letting the next bed, A2, come down on to the upper Greensand. Probably there has been some erosion of the latter, and A1 occupies the hollow so made, but the irregularities of the cliff and the growth of grass and bushes make it difficult to be sure of this. This A1 is clearly the equivalent of the lower part of the Bed A at Beer Head and Hooken, and as A2 contains *Pecten asper*, I regard it as the upper part of that bed, B being here very thin, and C is not represented.

This reading is confirmed by another exposure further west, in a bluff near the top of the cliff, more than half a mile west of the Coastguard Station and above the low-water inlet called the Cove. The arrangement of the beds in this bluff is shown in Fig. 34, which is taken from a rough sketch made on the spot.

		ft.	in.
Turonian.	Rough whitish chalk, with yellowish nodular lumps and yellowish gritty limestone at base	8	0
Zone of *Am. Mantelli.*	B. Rough gritty limestone, loose and weathered	0	9
	A2. Hard rough shelly limestone	1	4
	A1. Hard rough calcareous grit, with large quartz grains and a few fossils, deepens from 6 inches to	3	0
Selbornian.	Massive calcareous sandstone	16	0

These three beds in Branscombe cliffs were identified by Mr. Meyer with his Nos. 10, 11, and 12. Westward the Bed A1 thickens again in a few yards to a depth of 6 feet, A2 being at the same spot only 9 inches, and B only 5 inches thick. Here the base of Bed A1 is piped into the cracks and rifts of the underlying rock, and spaces of some size are filled with it.

In the next bluff, about 130 yards to the west, A1 is absent altogether, A2 has a thickness of 2 feet 9 inches, and there are traces of B above it.

A quarter of a mile further west, below Berry cliff and above Red Rock path, is a fallen block in which these beds are conveniently exposed for examination. The lower bed here (A2) is a hard gritty and shelly limestone, with a clear basal plane of separation; but B is represented only by 4 or 5 inches of rough gritty stone welded on to the lower bed, and full of brown phosphatised lumps.

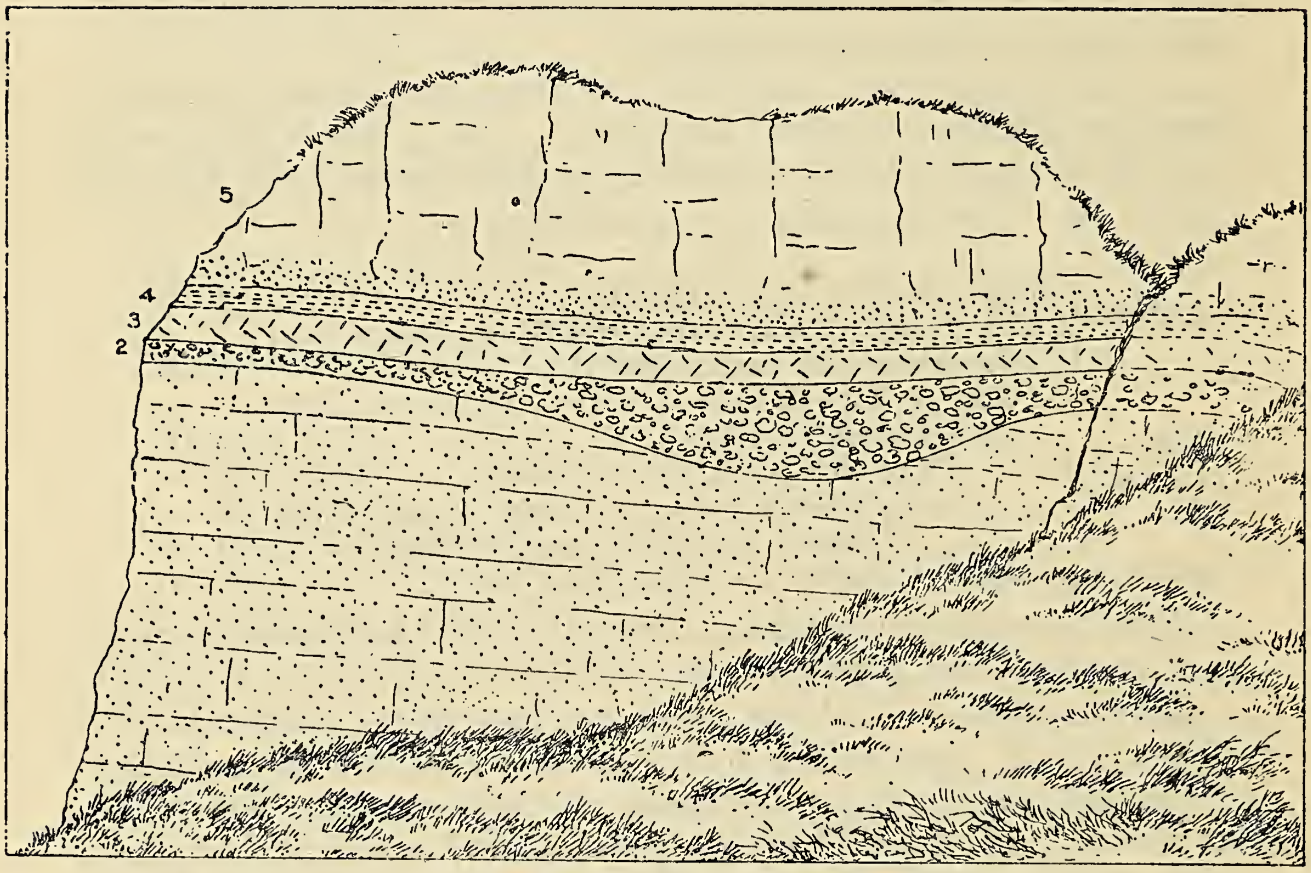

Fig. 34.—Sketch of a Bluff in Branscombe Cliffs, Devon Coast.

5. Middle Chalk with yellowish gritty limestone at the base.
4. Rough gritty limestone. (B.)
3. Rough shelly limestone (A2).
3. Coarse calcareous grit (A1).
1. Massive calcareous sandstone (Selbornian).

Where next seen in the cliffs above Donkey Linhay rocks the bed B seems to have thinned out entirely, and there is no trace of the rough grit (A1), the sole representative of the Cenomanian being the hard compact shelly limestone (A2), glauconitic and quartziferous, thickness 2½ feet. Many fossils can be seen in this, but it is almost impossible to extract them. I saw here three specimens of *Pecten asper* quite close to the top, and I never found this species in the higher bed B.

From the foregoing account of the exposures in Branscombe cliffs it will be seen that the Cenomanian is here a very variable group, consisting of three separate beds, each of which varies greatly in thickness. The lowest of the three is the most local, often thinning out entirely in a very short distance; the highest seems to thin out very gradually westward, but the middle bed nowhere quite thins out, and remains where the other two are absent.

There is, however, an interesting section in a quarry about a quarter of a mile N.N.W. of Branscombe Church, on the eastern slope of Culverhole Hill. This is :—

		ft.	in.
Turonian	Rubbly soil and whitish nodular chalk - - - -	2	0
	Hard yellowish limestone, nodular at base - - -	1	0
Cenomanian	B. Hard compact whitish gritty limestone, with green-coated nodules at top - - - - -	0	9
	A. Rough gritty and pebbly rock, with casts of shells and sandstone pebbles, and *Ceriocava ramulosa* near the base - - - - - -	6	6
Selbornian.—Massive calcareous sandstone - - - -		15	0

Bed B is similar in character and in thickness to the corresponding bed in the cliff sections, while that lettered A seems to be the portion which I have there called A1. It is one homogeneous mass from top to base, coarsest at the bottom, but without any divisional plane, and not specially compact or shelly at the top. It would seem therefore that the Bed A2, so persistent in the cliffs, is here absent.

There were formerly good sections in the quarries on Culverhole Hill, but these are now disused and overgrown.

Returning to the cliffs west of Littlecombe Hollow, the beds rise to such a high level and the cliffs present such an unbroken face above the lower slope that the Chalk cannot be reached without dangerous climbing. On the shore below Weston cliff, however, there is a fallen block which shows that all three beds of the Cenomanian group have come in again at that place. This block gave the following measurements :—

		ft
B.	Hard rough whitish limestone, with rather large quartz grains, green-coated lumps in the upper half, *Holaster subglobosus* - - - - - - - - - -	1
A2.	Very hard compact limestone, with many shells and Bryozoa, *Trigonia vicaryana* and *Am.*[*Acanth.*] *Mantelli*	2
A1.	Rough shelly calcareous grit, with large quartz grains, Pectens, Sponges, and *Ceriocava ramulosa* - - -	1½

A few inches of hard chalk with scattered quartz and glauconitic grains adhere to the top of B.

Crossing Weston Gap, we come to that part of Dunscombe cliffs which is known as Kempstone Rocks, and which seems to be part of the cliff face in its natural position. It may be noticed, however, that while the Cenomanian base in Weston cliff rises to the 500 feet contour, at Kempstone Rocks it has fallen to about 430, the probability being that a fault with downthrow to the west runs along the valley between Weston and Dunscombe.

At the eastern end of Kempstone Rocks the uppermost bed of the Greensand has been quarried away, and in the recess thus left an interesting section of the beds which overlie it is seen (Fig. 35).

		ft.	in.
B.	Whitish gritty limestone with a chalky matrix, weathering into lumpy layers, few fossils; layer of green-coated nodules at the top - - - - - -	1	9
A2.	Hard compact greyish shelly limestone - - - -	2	0
A1.	Coarse grit with calcareous cement, some fossils, especially *Ceriocava ramulosa* near base - - up to	2	0

The lowest bed, A1, is 2 feet thick in the corner, but thins out entirely in a few yards, leaving only A2 and B to continue westward. These can be reached at the top of a gully about the middle of the cliff-face, Bed A2 here yielding *Am.* [*Acanth.*] *Mantelli*, *Am.* [*Hoplites*] *curvatus*, *Trigonia vicaryana*, *Inoceramus striatus* and *Lima* (cast). From B I obtained *Septifer lineatus*, *Pleurotomaria* sp., *Rhynchonella dimidiata*, *Terebratella pectita*, *Discoidea subuculus*, and the claw of a Crustacean.

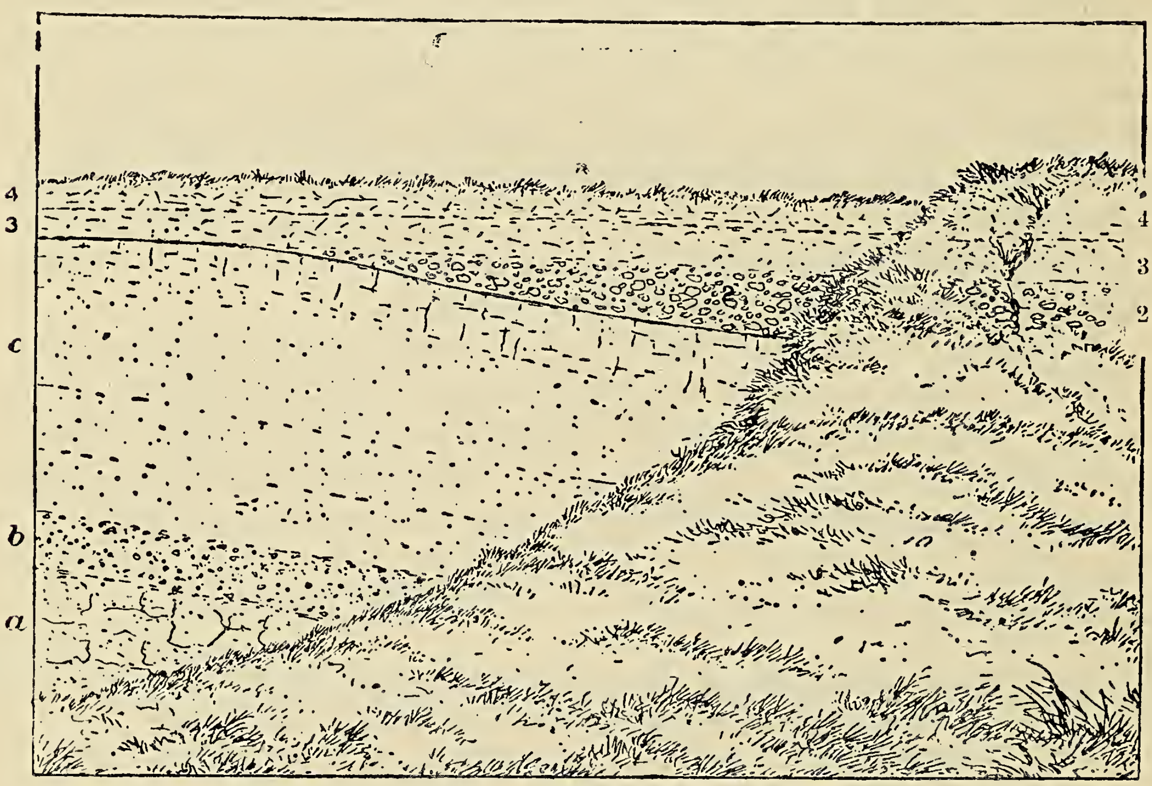

FIG. 35.—Sketch of an Old Quarry at Kempstone Rocks.

4. Whitish gritty limestone (B).
3. Compact shelly limestone (A2).
2. Coarse calcareous grit (A1).

c. Calcareous sandstone }
b. Coarse quartz-sand } Selbornian.
a. Calcareous sandstone }

There is an old quarry further inland east of Dunscombe Farm where the same beds are exposed, but are only accessible in one place; here A1, with its usual characters and fossils, varies from 15 to 30 inches in thickness, and is overlain by a massive compact limestone, which appears to be A2, while at this point B seems to be represented by a layer of green-coated nodules. A few yards off, however, blocks of Bed B, having the usual aspect of a whitish gritty limestone with large *Rhynchonella,* but few other shells, lie on the grass and testify to its existence above ; with them are squared blocks of the shelly limestone (A2), which seem to have been used for building stone.

At the top of the east end of Higher Dunscombe cliff the base of the Middle Chalk can just be reached. Below it are 2 feet of Bed B, containing large *Rhynchonella dimidiata,* and rather more than 2 feet of hard, whitish shelly stone (A2). In the old quarry near by the outcrop of the latter can be seen, and below are 18 inches of coarse pebbly grit with some fossils (A1), resting on massive calcareous sandstone.

The course of these beds along the cliff-top could not be reached without risk of life, unless, perhaps, by the aid of men and a rope ; but, fortunately, we are not left without evidence that all three Cenomanian beds continue and actually thicken locally to the westward. This evidence is obtained from the large fallen blocks which lie on the shore below the western part of the cliff, which is known as Maynard's cliff. One of these gave a vertical succession of about 9 feet, the whole belonging to the zone of *Am. Mantelli,* and having the following composition :—

B. Hard gritty limestone with white chalky matrix, large quartz and small glauconite grains ; many large green-coated lumps throughout the mass, these are brownish inside, but consist of the same material as the rest ; the base of this is welded on to the next. Thickness, 2 feet.

A2. Very hard sandy limestone of finer grain, full of shells and hard whitish calcareous lumps, some of which are Bryozoa (*Membranipora,* etc.), passing into next. Thickness, about 4 feet.

A1. Rough calcareous grit, shelly in upper part, becoming very coarse in lower part, with some quartz grains as large as peas *Ceriocava ramulosa* very common in lower part.

This block included from 3 to 3½ feet of the lowest bed, but another one showed about 4 feet, with a flat lower surface, which was probably the basal plane. Corals were common in the lower 3 feet of this ; but in neither block was there any sharp division between A1 and A2, the one passing into the other more completely than in any other exposure seen to the west of Hooken cliffs. The change from coarse to finer-grained rock is, however, rather rapid. It is curious that at this, the most westerly outcrop of the Cenomanian, its thickness (10 feet) should be greater than it is anywhere else along the coast, except at Hooken and Beer Head.

Bed B is clearly Mr. Meyer's 12, and yields *Holaster subglobosus, Rhynchonella dimidiata, Rh. grasiana,* and *Kingena lima.*

Bed A2 (Mr. Meyer's 11) contains many fossils, of which the commoner are *Trigonia* (several species), *Discoidea cylindrica, Cottaldia Benettiæ, Pseudodiadema ornatum, Neithea æquicostata* and *Terebratula ovata.*

The lowest bed is Mr. Meyer's No. 10, and contains the characteristic coral-like *Ceriopora.*

SUMMARY.

From the above descriptions it will be seen that between Sidmouth and Branscombe Mouth the Cenomanian is naturally divisible into three beds, and Mr. Meyer, who worked from Sidmouth eastward, was perfectly correct in distinguishing three separate beds. One would certainly have supposed that they would be equally distinguishable at Hooken Cliff and Beer Head, where the group attains its maximum development, but this is not the case, for at these points there are only *two* beds. To account for this, three suppositions may be made: (1) The middle bed may have thinned out and disappeared, (2) it may have become amalgamated with the upper bed, or (3) with the lowest bed.

In 1874 Mr. Meyer thought he found it in the lower part of the upper bed, but I cannot agree with that view; the differences, both faunal and lithological, seem to me considerable, and I regard the whole of the upper bed (B) at Hooken simply as an expansion of Mr. Meyer's No. 12. The abundance of *Holaster subglobosus* seems to me nearly sufficient to settle the point.

On the other hand, nearly all the fossils which occur in No. 11 (A2) of the more western sections have been found in the upper part of the lower bed at Hooken and Beer Nead. *Ammonites Mantelli*, *Pecten asper*, the large Limas, several *Trigoniæ*, and the peculiar *Holaster altus* are common in both. Both are fine-grained shelly limestones, and we have seen that in the fallen blocks below Maynard's Cliff there is a complete downward passage from No. 11 (A2) into No. 10 (A1). Hence it seems to me highly probable that there is a similar amalgamation at Hooken, and that the 18 feet of rock at Hooken which Mr. Meyer referred to his Bed 10 is really equivalent to both 10 and 11.

In passing round Beer Head this combination of 10 and 11, which I have called Bed A, can be seen in the process of thinning till it is condensed into a bed not more than 3 feet thick. This thinning is partly condensation and partly a thinning out of its lower portion, *i.e.*, of the representative of 10, and nowhere along the Beer Cliffs did I see any of the coral-like *Ceriocava ramulosa*, so that it is either absent or rare. Here, as elsewhere, it is, in my opinion, Bed 11 or the upper part of A which is most persistent, and which has yielded by far the larger number of fossils that have been collected from the Cenomanian of the Devon cliffs.

At Beer and Whitecliff the total thickness is in places reduced to less than 2 feet, and the upper bed (B) is always thinner than the lower bed (A). The composition of the beds in the more eastern cliffs has already been sufficiently explained.

CHAPTER XI.

THE LOWER CHALK IN SOUTH WILTSHIRE.

GENERAL DESCRIPTION.

Having in the preceding chapters described the Lower Chalk of Dorset and Devon, we now take up the formation again near Shaftesbury, on the borders of Dorset and Wiltshire, and will follow its outcrop thence across England.

From Charlton, near Shaftesbury, the Lower Chalk passes along the northern slope of the range of hills which forms the northern border of Cranborne Chase, and entering the Vale of Broad Chalk, extends as far as the west end of Ebbesborne Wake, where it passes beneath the Middle Chalk. This, however, is not its final disappearance, for, owing to a series of dome-shaped flexures which have bulged the beds upward, the Lower Chalk comes to the surface again in no less than four separate inliers to the eastward. The first of these is a small one south of Ebbesborne; the second is much larger, and surrounds the inlier of Selbornian Greensand at Bower Chalk; the third extends from Broad Chalk to Bishopstone, but mainly on the southern side of the river Ebble; the fourth and last is a small tract, almost entirely concealed by gravel and alluvium, by Combe Bissett and Homington.

The manner in which the Lower Chalk is thus brought up again and again is shown by the section Fig. 36, which has been drawn so as to traverse three of these inliers. It must be remembered that the flexures shown in this section are periclines, not axes, and that sections drawn at right angles to it would show the beds dipping both to the northward and to the southward.

Northward, indeed, they plunge under the bold ridge of Chalk Downs which runs from White Sheet Hill to Salisbury Racecourse. The main outcrop of the Lower Chalk passes round the west end of White Sheet Hill, and thence north-eastward along the southern side of the Vale of Wardour. Its outcrop terminates eastwards in the fine natural amphitheatre of Hoop Side, south of Barford.

On the northern side of the Vale the outcrop is narrower than on the southern side, partly because of the higher dips and partly because it is in places traversed by the fault which runs through Baverstock, Chilmark, Hindon, and Mere. Between Baverstock and Hindon the northerly dips of from 15° to 25° cause the Upper Greensand to stand up as a ridge, while the Lower Chalk, yielding more readily to detritive agencies, occupies a parallel longitudinal depression or trough (see Fig. 37).

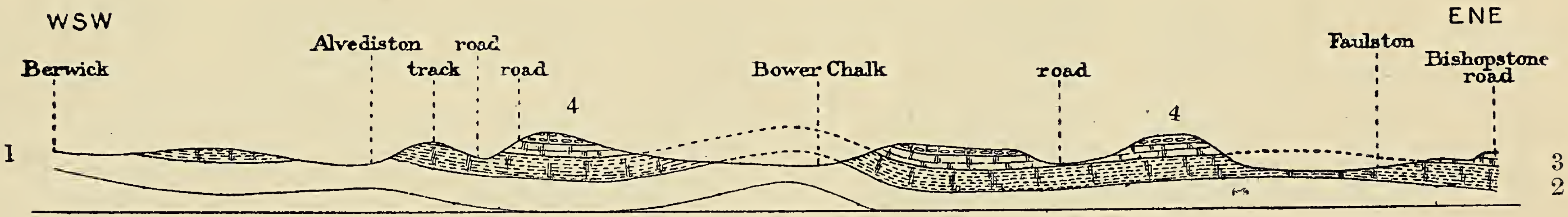

FIG. 36.—Section along the Vale of Broad Chalk.

Horizontal Scale about three-quarters of a mile to an inch.

4. Upper Chalk.
3. Middle Chalk.
2. Lower Chalk.
1. Selbornian.

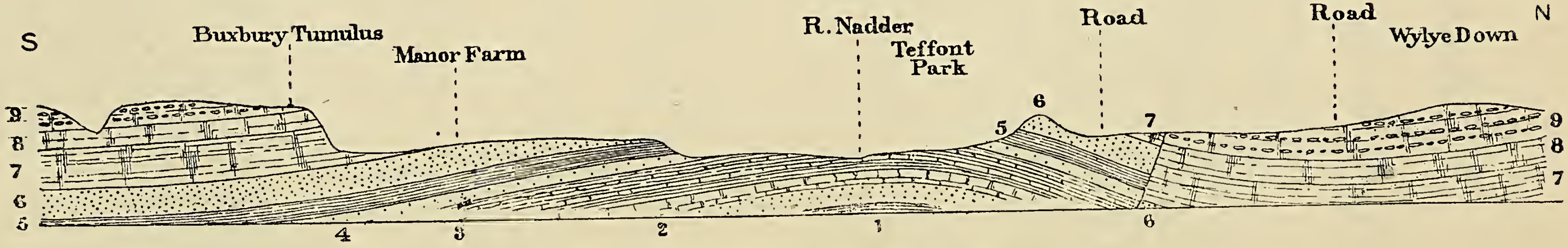

FIG. 37.—Section across the Vale of Wardour.

Horizontal Scale one mile to an inch. Vertical Scale, 1,200 feet to an inch.

9. Upper Chalk.
8. Middle Chalk, 100 feet.
7. Lower Chalk, 200 feet.
6. Upper Greensand, 160 feet.
5. Gault, 90 feet.
4. Lower Greensand and Wealden, 60 feet.
3. Purbeck.
2. Portland Beds.
1. Kimeridge Clay.

From the line of fault near Mere the boundary of the Lower Chalk runs northward to the hill called the Long Knoll, near Maiden Bradley; passing round this, it comes within the influence of Warminster uplift, and runs eastward to Longbridge Deverill and Heytesbury. Thence with a northerly dip it passes to Warminster and Cley Hill; curving round this it trends north-eastward to Westbury, and thence eastward in a fine escarpment above the villages of Bratton, Edington, Earl Stoke, and Cheverell to Market Lavington.

With respect to thickness, near Shaftesbury and Berwick St. John it appears to be about 180 feet, but on the north side of the Vale of Wardour it is probably about 200 feet, and near Warminster it appears to be nearly 250 feet, a greater thickness than it attains in any other part of England.

In the Vale of Wardour the zone of *Ammonites varians* has a considerable thickness, probably over 100 feet, but as there is no continuous section through the Lower Chalk, we cannot say how far up its fauna extends.

The zone of *Holaster subglobosus* is probably from 80 to 90 feet thick, but that fossil seldom occurs in this district, while *Am.* [*Haploceras*] *Austeni* is not uncommon in this massive part of the Lower Chalk and might be regarded as locally an index-fossil to the zone.

The thin band of grey marl, occasionally containing *Actinocamax plenus*, occupies its usual position.

STRATIGRAPHICAL DETAILS.

Zone of Ammonites varians.

Basement Beds—The base of the Chalk is seldom exposed in this district, and its junction with the underlying sands has only been seen at one or two distant points. One of these is in a small pit south-west of the village of Charlton, near Shaftesbury; this was visited by Mr. Rhodes in 1894, and he reported the section as a poor one, showing a little Chalk Marl, passing down into glauconitic marl, with marly glauconitic sand below. The succession is apparently similar to that in the quarry north of Melbury Hill, which is less than two miles distant (see p. 104). The glauconitic marl contains a few phosphates and some of the usual fossils, *Am.* [*Schl.*] *varians, Scaphites æqualis,* etc., and from the glauconitic sand Mr. Rhodes obtained *Pecten asper, Lima* (new sp.) *Exogyra plicata,* and *Catopygus columbarius.*

I did not find any exposure of the Chloritic Marl along the south side of the Vale of Wardour, east of White Sheet Hill, and the only good exposure of it on the north side of the Vale is in the roadway through the wood at Knoyle Corner, about a mile east of East Knoyle. The beds here seen are:—

	ft.	in.
Hard chalk marl with (microscopic) glauconite grains	3	0
Soft glauconitic marl, with an *Am.* [*Schloenb.*] *varians* in phosphate	0	8
Hard sandy and glauconitic chalk	0	6
Soft glauconitic chalk, marly at top, very sandy below	2	6
Hard glauconitic sandstone (see Vol. 1, p. 232.)	2	0

West of Mere and opposite the opening of the road to Gillingham is a quarry that has been worked for some time, and exposes the whole series of junction beds, dipping at about 5° to the east. This section has been carefully examined by Mr. John Scanes of Maiden Bradley, and has been described in a recent paper* from which the following account is taken :—

		ft.	in.
A.	Surface soil	0	6
	Pale yellow chalky wash and rubble	4	0
B.	Hard compact chalk marl, becoming glauconitic toward the base	3	0
	Softer sandy marl with a few large quartz grains	0	4
	Compact glauconitic marl, forming a solid bed, with large phosphatic nodules and many fossils	1	8
	"Popple Bed," calcareous glauconitic sand, full of brown-coated calcareous concretions, from 1 foot to	1	6
C.	Hard calcareous sandstone ; varying from 2 to	1	0
	Softer sands with lenticular masses of chert	6	0
		18	0

The beds in bracket A belong to the Selbornian, those in the bracket B we now regard as belonging to the zone of *Ammonites varians,* while C are surface accumulations.

The matrix of the "popple-bed" is hard, and resembles a sandy mortar. The "popples" are flattish oval lumps of calcareous stone from 2 to 5 inches long. Many of the fossils are well preserved and the bed is clearly marked off both from the underlying sand and from the sandy marl above. This latter is also hard and compact, and though fossils are abundant they are not readily released from the matrix.

The excellent section in the quarry at Maiden Bradley has been given in Volume I. of this Memoir, and in the paper above mentioned, but particulars of the beds which seem to be referable to the Cenomanian may now be given. These have been noted by Mr. Scanes, who has repeatedly examined the section, and has collected indefatigably from each of the beds disclosed :—

			ft.	in.
		Surface soil	2	0
Cenomanian	5	Glauconitic marl, with phosphatised fossils and fragments of brown phosphate, marly above, more sandy below, the lowest 6 inches being a compact sandy glauconitic marl	2	0
	4	Brownish glauconitic sand, with a layer of brown phosphatic nodules and phosphatised fossils at the base	0	6
	3	Bed of hard concretions, locally known as "cornstones," embedded in brownish-green sand	1	0
Selbornian.	2	Glauconitic sand, with scattered concretions of hard calcareous stone	2	9
	1	Chert Beds, seen for about	9	6
			17	9

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* Quart. Journ. Geol. Soc., Vol. lvii., p. 96, 1901.

The layer of "cornstone" concretions (No. 3) appears to be on the same horizon as the "Popple Bed" of Mere, and I now regard it as the base of the Cenomanian stage, but there seems to have been some local current action whereby many fossils have been sifted out of the original bed and accumulated in a layer on the top of the "cornstones;" most of them, however, are well preserved, and not rolled, so that they have not been carried far from their original position. This layer, now the base of No. 4, may be described as a phosphatic conglomerate, and is about 3 inches thick; it passes up into a fine brownish sand which is also about 3 inches and is likewise rich in fossils. The commonest fossils in this band are:—

Ammonites [Hoplites] falcatus.
,, [Acanth.] navicularis.
,, [,,] Mantelli.
,, [Schloenb.] varians.
,, [,,] Coupei.
Turrilites Morrisi.
,, Wiesti.
Nautilus expansus.
,, deslongchampsianus.
Avellana cassis.
Pleurotomaria (casts).

Solarium bicarinatum.
,, ornatum.
Ostrea canaliculata.
Cucullæa mailleana.
Pecten asper.
,, robinaldinus.
Terebratula biplicata.
Catopygus columbarius.
Holaster lævis.
Discoidea subuculus.
Pseudodiadema Benettiæ.

There is no break between beds 4 and 5, the latter being almost a sand at its base. Passing up this becomes a very sandy marl of a greenish-grey colour, which contains larger grains both of quartz and glauconite, and this merges upward into Chloritic Marl of the usual character. Throughout the whole of this 2 feet broken fragments of dark brown phosphate are scattered, with a few phosphatic nodules and many casts of fossils; but with these are many fossils with calcareous shells, which are clearly contemporaneous and not washed out of older beds. The following are some of the commoner species found in this bed:—

Ichthyosaurus campylodon (tooth.)
Ammonites [Schloenb.] varians.
,, [,,] Coupei.
Turrilites tuberculatus.
Scaphites æqualis.
Avellana cassis.
Emarginula Gresslyi?
Inoceramus latus.
Lima globosa
,, aspera.

Plicatula inflata.
Ostrea vesicularis.
Thracia carinifera.
Rhynchonella grasiana
Terebratella pectita.
Terebratulina striata.
Kingena lima.
Galerites castanea.
Peltastes clathratus.
Stauronema Carteri.

At Rye Hill Farm, 3 miles E.N.E. of Maiden Bradley, there are two small sand pits, and in 1900 one of these was deepened by Mr. Scanes, in order to get a complete vertical section through the beds at the base of the Chalk. The succession was then found to be as follows:—

	ft.	in.
5. *Chloritic Marl*, with phosphatic nodules and fossils -	2	0
4a. Greenish-grey glauconitic sand, with many fossils but without phosphates - - - - - - - - -	1	2
4. Soft yellowish-brown sand, with some lumps of hard concreted sand and many fossils - - - - - -	0	5
3. Greenish sand, with scattered "cornstones" - -	0	9
2. Soft greenish-grey sand, with scattered calcareous concretions, few fossils ; seen for - - -	2	3
	6	7

Of these beds, No. 3 is clearly the equivalent of the Cornstone bed at Maiden Bradley, but is less disturbed, and there is much more sand between the stones. The overlying brownish sand corresponds with the similar layer at Maiden Bradley, but there is no layer of phosphatic nodules at its base. This Bed 4 passes up into 4a, the change being chiefly one of colour, but the latter has no counterpart at Maiden Bradley; it is a sharp greenish sand, in which casts of *Am.* [*Schloenbachia*] *varians* in a pale yellow calcareous material occur plentifully, with many Brachiopods, especially *Rhynchonella grasiana, Rh. dimidiata, Terebratula biplicata*, and *Ter. arcuata; Catopygus columbarius* is also common. This bed has hitherto been regarded as belonging to the Upper Greensand, but I am now disposed to include it in the zone of *Ammonites varians*, and to take the Cornstone Bed (both here and at Maiden Bradley) as the base of this zone. It was probably from exposures of Beds 4 and 4a that most of the so-called Warminster fossils were obtained, and consequently, if the above conclusion be adopted, the greater part of the Warminster fauna will have to be transferred to the Cenomanian. A list of these fossils has been given in the first volume of this memoir.

It would appear, therefore, that in this part of Wiltshire there are beds below the subzone of *Stauronema Carteri* which must be classed with the Chalk rather than with the Selbornian. For this new subzone *Catopygus columbarius* may be taken as an index, as this fossil is very common in these beds, and is rare in the Chloritic Marl above them.

There is no open exposure of these beds near Warminster, but in 1889 I was fortunate enough to find a large cess-pit being dug for a new house north-west of St. Denys' Church. This was 11 feet deep, and showed 7 feet of glauconitic marl, the lower part rather hard and sandy, with many phosphates, the upper part more marly with fewer phosphates. The base was not reached, so that the total thickness may be 8 or 9 feet.

Its junction with the Greensand is, however, shown a little further north in a sand-pit by the side of the road south of Dilton. There is here a complete passage down from hard glauconitic marl through sandy marl to greensand, in a thickness of about 3 feet; the marly beds contain scattered phosphatic nodules, while the sand below has none. *Stauronema Carteri* was found in the hard marl. The road cutting south of the pit shows several feet of hard glauconitic chalk, much resembling mortar, passing up into softer chalk with little glauconite.

No exposure of the base of the Chalk was seen at Westbury, but there are several at Bratton, Tinhead, and Earlstoke. Thus a road-cutting near Combe Farm, Bratton, shows the following beds, for the description of which I am indebted to Mr. W. H. Bell, F.G.S.

	ft.
Rather hard light-grey marly chalk, with *Am.* [*Schloenb.*] *varians*, softer and darker below - - - - - -	10
Band of harder chalk - - - - - - - - - -	2
Soft dark grey marl with patches of green grains - - - -	1
Glauconitic marl, sandy at the base - - - - - -	2
Greensand below.	

A similar section, but exposing more of the sands below, is exposed in the quarry south of Tinhead, the Chloritic Marl being only 2 feet thick and containing only a few scattered phosphatic nodules. Compared with its development near Warminster it is much reduced in thickness, and forms a more distinct and separate bed, although there is no definite plane of separation at its base. Fossils also are scarce in this district.

Chalk Marl.—A good exposure of the alternating beds of soft marl and hard chalk forming the upper part of the *Am. varians* zone occurs in the chalk-pits by the side of the road leading up Buxbury Hill, on the south side of the Vale of Wardour, and is seen in the lowest level leading to the door of the lime-kiln, the descending succession being as follows :—

	ft.	in.
Two courses of hard rough grey chalk separated by loose marly chalk - - - - - - - - -	2	6
Dark grey argillaceous marl - - - - - -	0	6
Loose grey marly chalk - - - - - - -	1	3
Hard grey chalk - - - - from 9 inches to	1	6
Marly grey chalk, weathering into loose fragments, with here and there patches of darker bluish-grey chalk (many fossils) - - - - - - - - - -	14	0
Very hard rocky grey chalk, rising from below the last near the entrance - - - - - - - - -	1	6
Dark grey tough marly chalk - - - - seen for	1	0
	22	3

These beds have a southerly dip of 4°, and contain many of the characteristic fossils of the Chalk Marl, such as *Rhynchonella Martini*, *Rh. grasiana*, *Lima globosa*, *L. aspera*, *Am.* [*Schl.*] *varians*, etc.

A quarry to the south-east of the village of Fovant shows a similar set of beds, which must be at about the same horizon. The upper part of the quarry is in firm, massive whitish chalk, of which about 50 feet is seen, and below this the following succession can be made out :—

		ft.
Hard greyish-white chalk in layers, having alternately a rough and a smooth fracture		6
Layer of soft grey marl		0
Hard grey chalk		3
Soft dark grey marly chalk		1
Dark grey sandy chalk, with visible grains of glauconite (many fossils)	about	15
Very hard light grey limestone		1
Soft grey marl below.		

The grey sandy chalk is not unlike Totternhoe Stone, and contains many of the same fossils, but there are no phosphatic nodules or fragments in it.

There are no good exposures of this zone on the north side of the Vale of Wardour, nor are there any worthy of special notice near Mere or Maiden Bradley.

West of Warminster and south-east of Clay Hill Farm siliceous chalk occurs in a small pit about 50 feet above the Greensand. Mr. W. Hill has examined a sample of it, and informs me that it contains much globular silica and many sponge spicules. It is a firm blocky greyish-white chalk, and about 6 feet are exposed. In the cart-track which passes by the pit six layers of hard chalk are seen, three above and three below the siliceous chalk, and one of these is also siliceous.

The lower beds are exposed in the railway cutting near Upton Scudamore. They consist of soft grey marly chalk in courses 3 or 4 feet thick, alternating with layers of hard grey chalk. These beds contain *Am.* [*Schloenb.*] *varians, Am.* [*Acanth.*] *Mantelli, Turrilites scheuchzerianus,* and other characteristic fossils. They dip gently southward, and south of the bridge some higher beds come in, which include a band of rather soft brownish-grey chalk, about 4 feet thick, which has much resemblance to Totternhoe Stone, but is too low in the zone to be its representative.

Some of the higher beds are visible at the bottom of the road leading to Upton Cow Down. These are about 100 feet above the Chloritic Marl, and consist of firm blocky chalk, with four courses of hard greyish-white chalk, which stand out as steps or ledges on each side of the cart-track.

The greater part of the Lower Chalk is well exposed in the road cutting south of Tinhead, between Lavington and Westbury. I did not visit this section myself, and am indebted to my friend the Rev. W. R. Andrews for the following account. The thicknesses are eye-estimates only, and the higher beds are not so clearly seen as the lower. The outcrop of the Melbourn Rock is not exposed :—

			ft.
Zone of *Hol. subglobosus.*	Soft light grey chalk	about	50
	Course of very hard chalk	„	1
	Soft light grey chalk	„	50
	Course of very hard chalk	„	1

			ft.
Zone of *Ammonites varians*, 137 feet.	Soft grey chalk - - - - -	about	2
	Firm greyish blocky chalk with siliceous nodules, in beds divided by soft grey chalk -	,,	20
	Hard grey chalk - - - - - - -	,,	1
	Firm greyish chalk in blue-hearted blocky courses, with marly layers between - -	,,	30
	Hard grey chalk - - - - - -	,,	1
	Firm blocky grey chalk, like that above -	,,	10
	Hard grey chalk - - - - - - -	,,	1
	Firm blocky grey chalk, as before - -	,,	40
	Soft marly chalk - - - - - -	,,	20
	Bedded chalk marl (seen in quarry) - -	,,	10
	Chloritic marl (see p. 151.) - -	,,	2
			239

Mr. Andrews obtained a good specimen of *Inoceramus cuneiformis* from one of the harder beds in the zone of *Am. varians.*

Zone of Holaster subglobosus.

The higher part of the Lower Chalk is exposed in several quarries and road cuttings in the southern part of the district. The principal of these are the following:—

The quarry at Cann, south-east of Shaftesbury, has already been mentioned.

A large quarry on the western slope of White Sheet Hill, about four miles north-west of Shaftesbury, shows 70 or 80 feet of greyish-white blocky chalk, from which Mr. Rhodes obtained *Am.* [*Haploceras*] *Austeni, Am.* [*Acanth.*] *rotomagensis, Nautilus deslongchampsianus,* and a few other fossils.

By the road leading up to Buxbury Hill there are two excavations in the higher part of the Lower Chalk. The first of these is in the quarry above the exposure by the limekiln previously mentioned. This shows about 25 feet of firm blocky greyish-white chalk, breaking as usual along more or less curved surfaces, so that the real planes of bedding are obscured. The following fossils occurred: *Am.* [*Acanth.*] *rotomagensis, Inoceramus sp., Ostrea lateralis, Pecten Beaveri, Terebratula semiglobosa,* and Mr. Rhodes subsequently found *Am.* [*Acanth.*] *Mantelli, Am.* [*Hapl.*] *Austeni* (a fragment), *Ostrea vesicularis,* and *Pecten orbicularis.* These species and the absence of *Am.* [*Schloenb.*] *varians* incline me to place these beds in the higher zone. If this is correct the floor of the quarry nearly coincides with the transition from one zone to the other.

On the other side of the road, and at a little higher level, there is a second quarry, showing the following beds:—

	ft.
Compact white chalk, weathering into courses with looser chalk between them - - - - - - - - -	5
Rather rough greyish-white chalk - - - - -	6
Marly parting.	

	ft.
Hard greyish chalk, with indefinite bands of very hard nodular grey chalk - - - - - - - - - - -	8
Massive compact blocky chalk, parting along curved surfaces, seen for	7
	26

The lowest blocky chalk is evidently a continuation of that in the other quarry. The nodular beds contain *Ammonites* (? *Austeni*) and *A. sussexensis*). They show a dip of 6° or 7° to the south-east. The Belemnite marls cross the road about 100 yards further up, and from them Mr. Rhodes got three specimens of the characteristic *Actinocamax.*

On the north side of the Vale of Wardour, and north of the hamlet of Ridge, a quarry by Pitchpenny Clump shows the Melbourn Rock resting on a layer of grey marl, with greyish chalk below, but the rest of the section was obscured by talus when visited in 1890.

A similar section is exposed in a chalk-pit about a mile north-east of Dinton, grey blocky chalk succeeded by a broken layer of grey marl passing below the Melbourn Rock, which dips north at about 20°.

No good exposures of these beds were seen near Warminster, but whitish blocky chalk is shown near the limekiln north of the town, and cannot be far below the Melbourn Rock.

The road section near Tinhead has been already given.

CHAPTER XII.

THE LOWER CHALK IN NORTH WILTSHIRE.

General Description.

The Lower Chalk of the Vale of Pewsey is a continuation of that between Westbury and Lavington. Its outcrop passes from Lavington north-eastwards to Urchfont, and then eastwards along the southern side of the Vale of Pewsey, entering the valley of the Avon as far as Chisenbury and the Collingbourn valley as far as Collingbourn Kingston. From Tidcombe, at the head of the Vale, the outcrop curves to the north-west, and becomes much narrower in consequence of the steeper inclination of the beds, which continues as far as Hewish. West of that the arch of the anticline is much flattened, and the Lower Chalk spreads out more over the Selbornian by the Altons and the Cannings. There are, moreover, outliers still remaining on the Selbornian area at Woodborough, Etchilhampton, and near Potterne.

The main outcrop passes below Roundway Hill, near Devizes, and thence northward above Heddington and Calstone to Cherhill, east of Calne. Beyond this the Lower Chalk forms a separate escarpment, and its higher beds occupy a considerable portion of the plateau which intervenes between this escarpment and that formed by the Chalk Rock and higher part of the Middle Chalk.

These features continue as far as Chiseldon, but beyond that the two escarpments come nearer together and the width of the ground occupied by the Lower Chalk becomes narrower.

The thickness of the Lower Chalk is probably about 240 feet throughout the whole area, this figure being arrived at from the levels on the six-inch maps at several places where the top and bottom of the formation are within a short distance of one another and the dip is slight.

There are no complete continuous sections through the Lower Chalk in this area, and, so far as we know, it has not been very diligently searched for fossils, so that the upper limit of the *Ammonites varians* zone has not been determined.

There is very little marly chalk in the zone of *Am. varians*, most of this zone consisting of blocky chalk, with occasional harder beds of grey chalk. It includes beds of whitish siliceous chalk, much of the siliceous matter consisting of sponge spicules and minute globules of colloid silica, the proportion of such silica sometimes amounting to over 20 per cent. of the mass. This siliceous chalk often contains lumps of bluish-grey siliceous stone, which may be regarded as flints which have not been completely silicified.

These immature flints were first found in a lane south-east of Eastcott, and were described by Mr. Hill and myself in 1889.*

The following description is taken from the account there given: "One of the beds contains many definite siliceous concretions of irregular shapes, comparable to nodules of flint or chert, but unlike such nodules in being so closely united with the surrounding matrix that they are not readily separated from it. They are very hard; when broken they are seen to be of a yellowish or bluish-grey colour, with a dull earthy fracture which is quite different from that of flint. Examined with a lens, the fractured surface is seen to be rough and granular, and has somewhat the appearance of a piece of grey chalk which has been hardened by an infiltration of gum or cement."

STRATIGRAPHICAL DETAILS.

Zone of Ammonites varians.

Chloritic Marl.—The basement bed of the Chalk is well exposed at several localities in this district. It is generally a bed full of phosphatic nodules and fossils, and the occurrence of *Stauronema Carteri* proves it to be the continuation of the subzone characterised by that species. Only in one locality (Urchfont) has any bed been observed that might be compared with the subzone of *Catopygus columbarius* at Maiden Bradley. In most places north of the Vale of Pewsey there are signs of erosion at the base of the *Stauronema* zone.

One of the best exposures is that in the lane south of Urchfont where the following succession was seen in 1888:—

		ft.	in.
Chalk.	Light-coloured glauconitic marl, with phosphatic nodules passing down into very sandy marl, highly glauconitic, with many phosphates	6	0
	Thin continuous layer of phosphatic nodules.		
Greensand.	Greensand, somewhat marly, with scattered phosphates and *Pecten asper*, passing into next	0	6
	Hard glauconitic sandstone, with *Pecten asper*	1	0
	Greenish-grey sand, with doggers of sandstone	5	0

The Selbornian part of this section has been described in a preceding volume. There is really a complete passage here from Greensand to Chalk, and though the above grouping represents my impression at the time it is possible that the six inches of green sand above the sandstone represents the Rye Hill sand. Fossils are abundant in the overlying Chloritic Marl, and a list of those obtained in two hour's search is given on p. 163.

The junction is seen again in the railway-cutting at Stert, but though this is less than two miles distant the beds have changed considerably, for at Stert the sands pass up into marly sand, and this becomes gradually harder and more marly, becoming a glauconitic marl or chalk with scattered phosphatic nodules; but of this there is only about 12 inches, and both the phosphates and fossils are much less abundant.

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* Quart. Journ. Geol. Soc., Vol. xlv. p. 403.

Mr. W. Cunnington, who formerly resided at Devizes, informed me that he obtained many fossils and phosphatic casts from a spot near the enclosed garden in Roundway Park. These fossils are now in the Museum of Practical Geology, and a list of them is given on p. 163. It would appear that there must be a small patch of Chloritic Marl here resting on the plateau of the Upper Greensand.

Another good exposure occurs on the road from Calne to Devizes, about half a mile west of Calstone. Here the Selbornian sands are directly succeeded by hard glauconitic marl, the base of which is piped into the sand. This glauconitic marl forms a solid bed 2½ feet thick, and is crowded with phosphatic nodules and fossils; above comes a second bed with fewer phosphates and less glauconite, which is about a foot thick, but passes up into Chalk Marl with still fewer green grains. *Pecten asper* occurs in the lower bed, but the shell is phosphatised and brittle. *Terebratula biplicata*, *Terebratulina striata*, *Rhynchonella grasiana*, *Pecten* (*Neithea*) *quinquecostatus*, and *Plicatula inflata* occur with perfect calcareous shells.

The glauconitic base of the Chalk is seen at Highway and Cleveancy, and still better in the cutting north of Chiseldon, on the Swindon and Marlborough Railway. My colleague Mr. Bennett furnishes the following note of this section:—"At the north end of the cutting, and overlying some 25 feet of Greensand, the phosphatic bed is seen dipping at about 7° southward. It is about 2 feet thick, the lower foot dark green with many phosphatic nodules; both green grains and nodules diminish in number upwards. Its base is marked by a line of reddish rusty material, probably from the decomposition of iron-pyrites."

Chalk of the Ammonites varians Zone.—Along the southern side of the Vale of Pewsey many of the deep-cut lanes which ascend the slope of the Chalk hills exhibit more or less continuous sections of the Lower Chalk.

The lowest beds, immediately above the Chloritic Marl, are well exposed in the lane south of Urchfont, and consist of marly chalk with *Am.* [*Schl.*] *varians* and *Am.* [*Acanth.*] *Mantelli*, and higher up of whitish blocky chalk.

The higher beds are also well shown in a lane ascending the escarpment south-east of Eastcott, and were described by Mr. Hill and myself in 1889.* The lowest exposure here is between 120 and 130 feet above the base of the Chalk, and is a small excavation showing about 10 feet of whitish, flaggy chalk, which proved to contain much globular colloid silica. It also contains many of the siliceous nodules already mentioned, these occurring in a band of from 12 to 18 inches in depth. At the top the chalk is greyish and harder, but still siliceous.

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* Quart. Journ. Geol. Soc., Vol. xlv. p. 405.

About 20 feet above this siliceous chalk a bed of very hard, compact, and heavy grey chalk, about 18 inches thick, crosses the roadway. Some 40 feet higher is another conspicuous bed, grey, but not quite so hard, 3 feet thick; this has some resemblance to Totternhoe Stone and examination with a microscope showed that it contained much glauconite and many fragments of silicified Inoceramus shell, but we do not consider it to be on the same horizon. A third hard bed, whitish and compact, occurs still higher, about half way between the last and the Melbourn Rock. The descending section is therefore as follows:—

		ft.
	Melbourn Rock at level of about 570 feet.	
Zone of *H. subglobosus.*	Whitish chalk	20
	Hard compact white chalky limestone	2
	Whitish chalk	20
	Rather hard grey gritty chalk	3
	Greyish-white chalk	40
	Very hard, compact and heavy grey chalk	1½
Zone of *Am. varians.*	Greyish-white chalk	20
	Rather hard greyish chalk	1½
	Soft whitish siliceous chalk	4
	Siliceous chalk with concretions	1½
	Soft whitish siliceous chalk - seen for	8½
	Chalk and chalk marl (not seen) - about	122
	Total	244

Near the eastern end of the Vale of Pewsey the Lower Chalk is exposed in several of the cuttings on the Swindon and Andover Railway. The following notes on these are furnished by Mr. F. J. Bennett:—The first cutting, about a mile S.S.W. of West Grafton, shows grey marly chalk with a kind of conchoidal fracture overlain by hard, grey, gritty chalk which dips southward at about 3°. The next cutting, about a third of a mile to the south, shows about 8 feet of hard, grey, gritty chalk weathering in a flaggy manner. A third cutting, about the same distance farther south and a little north of Collingbourne Kingston, is about 9 feet deep in soft greyish chalk. In the trackway leading to East Grafton, and about a mile east of the first cutting, hard siliceous chalk was seen, containing blue-hearted siliceous concretions, and similar chalk was seen in the high road west of Wexcombe Church.

Mr. T. Codrington, describing the cuttings on the Marlborough Railway in 1865,* states that in the cutting "at Lye Lane there is a good section through part of the Lower Chalk, here consisting of hard, thick-bedded stone, dipping north at 8°." In this he found the following fossils:—*Inoceramus latus, Pecten Beaveri, Pecten (Neithea) quinquecostatus, Rhynchonella Gibbsi* [? *grasiana*], *Am.* [*Schl.*] *varians, Am.* [*Acanth.*] *Mantelli, Turrilites tuberculatus*, and Sharks' teeth.

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* Mag. Wilts. Arch. and Nat. Hist. Soc., Vol. ix. p. 167.

Another place where several small but successive sections in the Lower Chalk may be seen is Ridgeway Lane, north of Alton Priors.* The lowest of these, about 50 feet above the base, is in ordinary Chalk Marl, full of minute grains of glauconite, and many shells of *Inoceramus latus,* d'Orb. The second is 20 feet higher, and shows a bed of hard grey chalk with less glauconite; this has the aspect presented by the hard beds which consist principally of comminuted shell fragments. The third exposure is about 10 feet higher and shows soft, blocky, grey chalk containing both glauconite and white mica in small flakes. About 70 feet higher, *i.e.*, about 150 feet above the base, is greyish-white chalk containing siliceous nodules and concretions of a bluish-grey colour, like those found at Eastcott and Collingbourn.

Siliceous chalk, but without concretions, was also seen in a small excavation north of Allington at about the 500 feet contour.

A good section of the lower 50 or 60 feet of the Chalk Marl is seen in a chalk pit east of Compton Bassett and along the neighbouring roadway. The bank east of the quarry shows 15 or 16 feet of soft, grey marly chalk, which is very argillaceous at the base, and the Chloritic Marl crops out just below. At the top of the bank is about 6 feet of firm blocky chalk, and 12 or 14 feet of similar chalk are exposed in the quarry face; this blocky chalk is full of minute grains of glauconite. Southward in the roadway several courses of much harder chalk weather out in distinct ledges, and microscopic examination of these showed them to contain much colloid silica in minute globules.

The roadway ascending the hill south of Cliff Pypard traverses the lower part of this zone, but the original section is now much talused and obscured. Judging from specimens, which I owe to the kindness of the Rev. E. H. Goddard, of Cliff Pypard, and from information supplied by him, there do not appear to be any hard beds here like those of Compton Bassett, all the chalk seen being greyish-white and blocky, but the highest part weathers into small flaggy slabs. Near the bottom of the main cutting, and just below the contour-line of 600 feet, the chalk is greyer and rather harder, and examination shows it to be full of small glauconite-grains; this probably marks the beginning of the passage into Chloritic Marl, and, though chalk extends much farther down the slope, it is probably in masses which have slipped from their original position. Mr. E. Meyrick and the members of the Marlborough Natural History Society obtained fossils from this cutting and sent them to me for determination (see list on p. 163).

Mr. F. J. Bennett informs me that on the top of the hill overlooking Broad Town, and by the side of the high road leading northward, are two quarries in the Lower Chalk about 60 feet above its base. The first shows about 10 feet of grey flaggy chalk; the second shows the following section :—

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* For the specimens and measurements of this section I am indebted to my colleague, Mr. F. J. Bennett.

	ft.
Grey flaggy chalk - - - - - - - - - - -	3
Grey marly chalk, weathering into balls - - - - - -	1½
Grey flaggy chalk - - - - - - - - - -	2
Marly chalk - - - - - - - - - - - - -	1
Grey chalk with curvilinear jointing - - - - - -	2
Massive grey blocky chalk, seen for - - - - - -	4

He obtained *Am.* [*Acanth.*] *cenomanensis, Nautilus elegans,* and *Lima elongata* from the quarries.

Similar chalk is exposed in the roads leading down the escarpment to Bassett Down House and to Lower Quidhampton.

A well sunk in 1901 at the farmstead on Bassett Down, belonging to Mr. N. S. Maskelyne, traversed a large part of the zone of *Am. varians* and most of the underlying malmstone. I am indebted to the contractor, Mr. J. W. Titt of Warminster, for particulars and for samples of the beds traversed, from which information and from notes taken by Mr J. Scanes the following account has been drawn up.

		ft.
Lower Chalk.	Alternations of hard and soft grey chalk - - - -	30
	Tough grey chalk, apparently without hard beds - -	30
	Rather hard grey chalk containing pieces of *Inoceramus latus, Am.* [*Schl.*] *varians* and *Nautilus elegans* -	20
	Hard bluish-grey chalk with *Inoc. latus* and *Am. varians*	10
	Bluish-grey marly chalk with *Am. varians* - - -	17
	Mottled grey and buff chalk-marl with *Am. varians* and *Turrilites Bergeri* - - - - - - - -	3 5
	Hard grey sandy chalk with some glauconite grains - -	1¼
Selbornian.	Dark grey sandy glauconitic chalk with blackish phosphatic nodules (Chloritic Marl) - - - - - -	0¾
	Grey fine-grained micaceous sandstone with some softer bands - - - - - - - - - - -	17
	Grey micaceous malmstone, partly hard and partly soft -	23
	Dark grey malmstone and sandy marl - - - - -	11
		165

The lower part of the zone is well exposed in the cuttings near Chiseldon Station, and the following account has been written from notes furnished by my colleague, Mr. F. J. Bennett.

"In the middle of the cutting north of Chiseldon Station about 40 feet of Chalk Marl is exposed. It consists of alternating soft and hard beds; the soft beds are the thickest, and consist of marly chalk, weathering into spherical lumps and traversed by oblique curvilinear joints or planes of separation; the hard beds consist of compact greyish chalk, are seldom more than 8 inches thick, but stand out as ledges along the face of the cutting.

"In the cutting south of Chiseldon Station the first chalk seen is firm, jointed, and bedded, but about half-way toward the first bridge a bed of hard grey, gritty chalk, full of small glauconite grains, comes in, and dips southward at about 3°. This bed has a remarkable structure containing much fine angular quartz-sand and much globular colloid silica. Similar beds come in further south, and at the bridge by Bush House, where the cutting is about 15 feet deep, there are three beds of hard, grey, gritty chalk, each about 6 inches thick with softer chalk between."

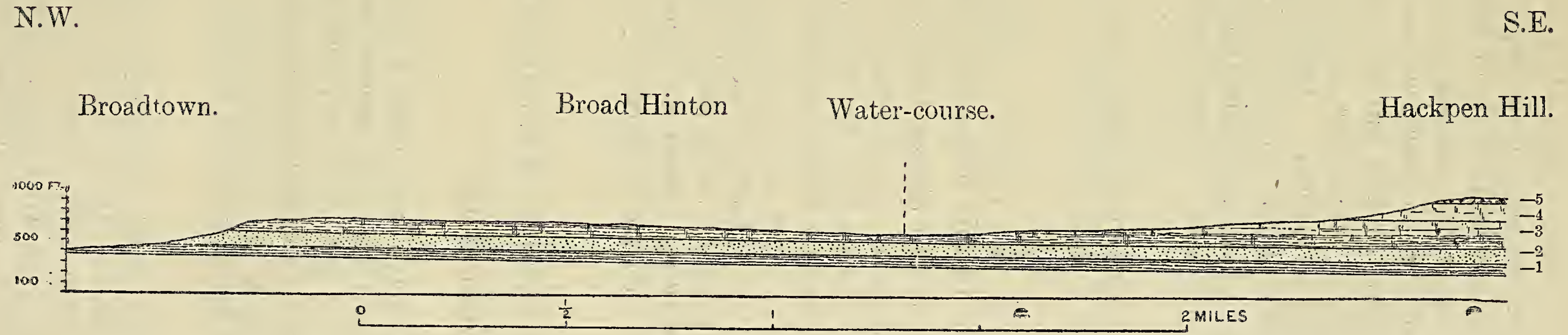

Fig. 38. Section from Broadtown to Hackpen Hill, in Wiltshire.

5. Upper Chalk.
4. Middle Chalk.
3. Lower Chalk, bedded below, blocky above.
2. Upper Greensand. } Selbornian.
1. Gault Clays. }

2. Zone of Holaster subglobosus.

The higher part of the Lower Chalk, or that which represents the zone of *Holaster subglobosus,* presents an unusual aspect in this part of Wiltshire. The beds of compact whitish chalk, of which it usually consists, are here divided by layers or courses of hard, greyish, gritty chalk, which weather out conspicuously on account of their hardness; moreover, a strong lens reveals the fact that they contain dark green or black grains of glauconite, a mineral which is seldom seen elsewhere at so high an horizon. There are sometimes three or four such courses of hard chalk, varying in thickness from 1½ to 3 feet. At the top of this chalk the Belemnite marl or subzone of *Actinocamax plenus* is probably always present, though it is not often exposed.

The exposure of these higher beds in the lane above Eastcott has been described on p. 158. Some of them can also be seen in the lane south of Urchfont.

The chalk in the cutting on the railway a little north of Collingbourn Kingston, may be in this zone (see p. 158).

On the north side of the Vale the higher beds are well shown in the roadway north of Allington. A succession of hard beds, five or six of them, cross the road. and form a set of steps or ridges. One about 80 feet below the Melbourn Rock is a hard grey siliceous chalk, containing much globular silica, and this may be taken as the top of the *Am. varians* zone. About 40 feet higher is a very gritty limestone, compact and heavy, with small grains of dark green glauconite; its grittiness being caused by minute fragments of Inoceramus shell, many of which are silicified.*

LIST OF FOSSILS FROM THE CHLORITIC MARL AND LOWER CHALK OF NORTH WILTS.

The following lists of fossils have been drawn up from several sources. As regards the Chloritic Marl, the entries under the heads of Urchfont, Stert, and Calstone are those of fossils obtained and identified by myself; those from Devizes were obtained by Mr. W. Cunnington, and are now in the Museum of the Geological Survey; those from Chiseldon are in the Museum of the Marlborough College Nat. Hist. Society.

Of the Chalk Marl lists, that from Savernake includes those mentioned by Mr. Codrington; those from Clyffe Pypard, Bincknoll, and Chiseldon are from collections made by the members of the Marlborough Coll. Nat. Hist. Soc., published in the Reports for 1889, 1897 and 1901; most of these fossils were sent to me for identification.

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* See Quart. Journn. Geol. Soc., Vol. xlv. p. 411.

List of Fossils from the Chloritic Marl and Lower Chalk of North Wilts.—*contd.*

	Chloritic Marl.					Chalk Marl.			
—	Urchfont.	Stert.	Devizes.	Calstone.	Chiseldon.	Savernake.	Clyffe Pypard & Broad Town.	Bincknoll.	Chiseldon.
Pisces.									
Lamna appendiculata, *Ag.*	1	–	–	–	5	a	–	–	d
Scapanorhynchus rhaphiodon, *Ag.*	–	–	–	–	5	–	–	–	–
		–	–	–	–	–	–	–	–
Cephalopoda.		–	–	–	–	–	–	–	–
Ammonites [Acanth.] cenomanensis, *d'Arch*	–	–	–	–	–	–	b	–	–
,, [Hoplites] curvatus, *Mant.*	1	–	–	–	–	–	–	–	–
,, [,,] falcatus, *Mant.*	1	–	–	–	–	–	–	–	–
,, [Acanth.] Mantelli, *Sow.*	1	–	–	4	5	a	b	c	d
,, [,,] navicularis, *Mant.*	–	–	–	4	–	–	–	–	–
,, [,,] rotomagensis, *Brongn.*	–	–	–	–	–	–	–	c	–
,, [Schloenb.] varians, *Sow.*	1	2	3	4	5	a	b	c	–
,, ,, Coupei, *Brongn.*	1	2	3	4	5	–	–	–	–
Hamites sp.	1	–	–	–	–	–	–	–	–
Scaphites æqualis, *Sow.*	–	–	3	–	–	–	b	–	d
Turrilites Bergeri, *Brongn.*	–	–	–	4	–	–	–	–	–
,, costatus, *Lam.*	–	–	–	–	–	–	b	–	d
,, Morrisi, *Sharpe*	1	–	–	4	–	–	–	–	–
,, scheuchzerianus, *Bosc.*	–	–	–	–	–	–	–	c	–
,, tuberculatus, *Bosc.*	1	2	–	–	–	a	–	c	–
,, Wiesti, *Sharpe*	–	–	–	4	–	–	–	–	–
Belemnites ultimus, *d'Orb.*	–	–	–	–	–	–	b	–	–
Nautilus elegans, *Sow.*	–	–	–	–	–	–	b	–	–
,, expansus, *Sow.*	–	–	–	4	–	–	–	–	–
,, deslongchampsianus, *d'Orb.*	1	–	3	4	–	–	b	–	d
,, Fittoni, *Sharpe*	1	–	3	–	–	–	–	–	–
,, largilliertianus, *d'Orb.*	–	–	–	4	–	–	–	–	–
Gasteropoda.									
Aporrhais sp. 1	1	–	–	4	–	–	–	–	–
,, sp. 2 (angulated)	–	–	–	4	–	–	–	–	–
Avellana cassis, *d'Orb.*	1	–	3	4	–	–	–	–	–
Collumbellina sp.	–	–	3	–	–	–	–	–	–
Emarginula Gresslyi, *P. & C.*	–	–	3	–	–	–	–	–	–
Murex bilineatus, *P. & C.*	1	–	?	–	–	–	–	–	–
Pleurotomaria brongniartiana, *d'Orb.*	1	2	3	4	5	–	–	–	–
,, perspectiva, *Mant.*	1	–	3		? 5	–	b	–	–
,, sp. (tall)	1	–	–	4	–	–	–	–	–
Phasianella sp.	–	–	3	–	–	–	–	–	–
Solarium martinianum, *d'Orb.*	–	–	3	–	–	–	–	–	–
,, bicarinatum, *Tiessen*	1	–	–	–	–	–	–	–	–
,, sp.	–	–	–	–	5	–	–	–	–
Trochus sp.	1	–	3	–	–	–	–	–	–
Turbo sp.	?	–	3	–	–	–	–	–	–
Lamellibranchiata.									
Anomia papyracea, *d'Orb.*	–	–	–	–	5	–	–	–	–
Arca carinata ? *Sow.* (cast)	–	–	–	4	5	–	–	–	–
,, passyana, *d'Orb.* (cast)	1	–	–	–	–	–	–	–	–
Aucellina gryphæoides, *Sow.*	1	–	–	4	–	–	–	–	–
Cardium mailleanum ? *d'Orb.*	1	–	–	–	–	–	–	–	–
Cardita tenuicosta, *Sow.*	–	–	3	–	–	–	–	–	–
Crassatella sp. (cast)	–	–	–	4	–	–	–	–	–
Cucullæa mailleana, *d'Orb.*	1	2	3	4	5	–	–	–	–
,, obesa ? *P. & R.*	1	–	–	4	–	–	–	–	–
Cyprina quadrata, *d'Orb.*	1	–	–	–	–	–	–	–	–
,, sp.	–	–	–	4	–	–	–	–	–
Inoceramus latus, *d'Orb.*	1	2	–	4	5	a	b	–	d
,, striatus, *Sow.*	1	–	–	–	–	–	–	–	–
Lima elongata, *Sow.*	–	–	–	–	–	–	b	–	–
,, globosa, *Sow.*	–	–	–	–	–	–	b	c	–
Ostrea canaliculata, *Sow.*	1	–	–	4	–	–	–	–	–
,, vesicularis, *Lam.*	1	–	–	–	–	–	–	–	–
Pecten asper, *Lam.*	–	–	–	4	–	–	–	–	–
,, Beaveri, *Sow.*	–	–	–	–	-	a	–	c	–
,, orbicularis, *Sow.*	1	–	–	–	–	–	b	–	–
,, Galliennei ? *d'Orb.*	1	–	–	–	–	–	–	–	–
,, (Neithea) quinquecostatus, *Sow.*	1	–	–	4	–	a	–	–	–
Pectunculus sp.	–	–	–	4	–	–	–	–	–
Plicatula inflata, *Sow.*	1	–	–	–	5	a	b	–	d
,, gurgitis, *P. & R.*	1	2	–	4	–	–	–	–	–
Thracia (Corimya) carinifera, *Sow.*	–	–	3	4	–	–	–	–	–
Unicardium ringmeriense, *Mant.*	1	–	–	–	–	–	–	–	–
Venus rotomagensis, *d'Orb.*	1	–	–	–	–	–	–	–	–

LIST OF FOSSILS FROM THE CHLORITIC MARL AND LOWER CHALK OF NORTH WILTS.—*contd.*

—	Chloritic Marl.					Chalk Marl.			
	Urchfont.	Stert.	Devizes.	Calstone.	Chiseldon.	Savernake.	Clyffe Pypard & Broad Town.	Bincknoll.	Chiseldon.
Brachiopoda.									
Rhynchonella grasiana, *d'Orb.*	1	2	–	4	5	a	b	–	–
„ Martini, *Mant.*	–	–	–	4	–	–	–	–	–
„ lineolata, *Phil.*	–	–	–	4	–	–	–	–	–
Terebratula biplicata, *Sow.*	1	–	3	4	5	–	–	–	–
Terebratella Menardi, *d'Orb.*	–	–	3	–	–	–	–	–	–
Terebratulina striata, *Wahl.*	–	–	–	4	–	–	–	–	–
Echinodermata.									
Discoidea subuculus, *Klein*	1	2	–	–	–	–	–	–	–
Pseudodiadema variolare, *Brongn.*	1	–	–	–	–	–	–	–	–
Annelida.									
Serpula umbonata, *Sow.*	1	–	–	–	–	–	–	–	–
Crustacea									
Palæga Carteri, *Woodw.*	–	–	–	–	–	–	–	–	d
Spongida.									
Siphonia ? (in phosphate)	–	–	–	4	–	–	–	–	–
Stauronema Carteri, *Sollas*	–	2	–	4	–	–	–	–	–

CHAPTER XIII.

THE LOWER CHALK IN BERKSHIRE.

GENERAL DESCRIPTION.

In the western part of Berkshire the Lower Chalk is probably about as thick as it is in the adjoining part of Wiltshire, namely, 240 feet, but in the north-eastern part near the river Thames its thickness has been calculated at not more than 220 feet.

It is in this county that the Totternhoe Stone makes its first appearance as a recognisable bed, but it has not yet been identified further west than the village of Chilton. The stratigraphical importance of this bed is that it occurs just at the horizon where *Ammonites varians* dies out, and so enables us to draw a line between the zones of *Am. varians* and *Holaster subglobosus.*

Thus in the northern part of Berkshire the succession and relative thicknesses of the beds are as follow:—

		ft.
5. Grey Marls with a bed of white chalk		2–3
4. White and grey chalk	about	75
3. Totternhoe Stone		2
2. Marly and blocky chalk	about	135
1. Glauconitic marl		2–5
	About	220

Nos. 1 and 2 make up the zone of *Ammonites varians,* Nos. 3, 4 and 5 form the zone of *Holaster subglobosus,* No. 5 being the subzone of *Actinocamax plenus.*

Above the Chloritic Marl there is some thickness of grey chalk marl in beds alternating with courses of harder grey chalk; higher up there is greyish-white, marly chalk, not very clearly bedded, and the upper 60 feet of the *Am. varians* zone consists of marly chalk with courses of hard siliceous chalk characterised by the presence of sponge spicules and globular silica.*

The Totternhoe Stone has been described on p. 15, and the small representative of it in Berkshire agrees with that description in all essential particulars.

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* See Quart. Journ. Geol. Soc., Vol. xlv., p. 403.

In Berkshire the zone of *Holaster subglobosus* loses the abnormal characters which it exhibits in Wiltshire, and assumes those which prevail both to the northward and to the eastward. The Wiltshire type is probably continued for some distance into Berkshire, and there are so few exposures in this western area that we cannot say precisely where the change takes place. Possibly it is coincident with the incoming of the Totternhoe Stone. At any rate, to the north of Wantage this zone consists of greyish chalk for a certain distance above the Totternhoe Stone, probably 30 or 40 feet, but this passes up into whitish blocky chalk without definite bedding, and of nearly the same character throughout.

The subzone of *Actinocamax plenus* is very thin in Berkshire, no exposure showing a greater thickness than 2½ feet, and, instead of consisting wholly or mainly of marl as in most of the southern and eastern districts, it here includes a bed of hard, white, compact chalk about a foot thick; lying generally between two layers of grey marl, this white bed is very conspicuous in section.

All the exposures mentioned in the following pages occur along the main outcrop, which runs from Ashbury in the west to Cholsey and Moulsford in the valley of the Thames. There are, however, two small inliers of Lower Chalk on the south side of the great escarpment; these occur in two of the deep valleys which traverse the downs north of Lambourn.

STRATIGRAPHICAL DETAILS.

Zone of Ammonites Varians.

Chloritic Marl.—The junction of the chalk with the underlying Greensand is not often exposed in Berkshire, but, wherever it has been seen, there is a complete passage upward from the glauconitic sand of the Selbornian through sandy glauconitic marl with fossils and phosphatic nodules into a marly chalk with scattered green grains. The passage is often so complete and gradual that it is difficult to say where the one formation ends and the other begins.

One of the best exposures is in a small sand pit by the side of the main road near Westcott, four miles west of Wantage. The section seen here in 1887 was—

			ft.
3	Chalk marl with minute green grains - - -	about	3
	Harder glauconitic marl with larger green grains -	„	2
2.	Green sandy glauconitic marl, with some phosphatic nodules and fossils - - - - - - -	„	2½
1.	Dark green sand - - - - - seen for	„	2½

Among the phosphates were *Am.* [*Schloenb.*] *varians*, *Nautilus sub-lævigatus ? Plicatula inflata*, and a *Pleurotomaria*.

A similar set of beds was exposed in the excavation for the Wantage Waterworks, half a mile south of the town, and from them many fossils were obtained by Mr. E. C. Davey, then a resident in Wantage (about 1878). Some of these were sent for my inspection, and among them I recognised the species above mentioned, together with *Avellana cassis, Solarium sp. Pecten asper,* and *Terebratulina triangularis.* His collection from the same horizon also included *Turrilites tuberculatus, Terebratula biplicata, Discoidea subuculus,* and other undetermined species.

Another good exposure of these beds will be found in the lane leading northward from Lockinge to the main road from Wantage, which here passes over a small outlier of Chalk Marl. This lane traverses the following beds :—

		ft.
3.	Hard grey bedded chalk, with many *Am.* [*Schl.*] *varians*	5
	Soft grey argillaceous marl	6
	Hard grey chalky marl—*Turrilites Bergeri*	1
	Hard glauconitic marl, with large nodular lumps of harder stone, enclosing *Am.* [*Schl.*] *varians, Strephinia convoluta,* and *Pleurotomaria*	3
2.	Sandy glauconitic marl with scattered phosphatic nodules, without a definite base	2½
1.	Green glauconitic sand (Selbornian).	

In this section No. 2 probably represents the Chloritic Marl or subzone of *Stauronema Carteri,* but I did not find any recognisable fossils in it. The overlying bed appears to correspond with that which overlies the Chloritic Marl in the Isle of Wight, and has been called the "niveau à *Plocoscyphia mæandrina*" by Professor Barrois.

Chalk with Ammonites varians.—The lowest beds of this zone are exposed in the road-cutting half a mile south-west of Kingston Lisle, the section seen in the bank being :—

		ft.
Hard rocky marl	about	3
Soft grey marl	,,	8
Hard glauconitic marl, seen for	,,	2

South of this and about 70 feet higher is a small quarry showing marly chalk, rather hard and blocky, with some softer layers, overlying a bed of very hard grey stony chalk containing *Am.* [*Schl.*] *varians, Turrilites scheuchzerianus, Inoceramus latus,* &c. Of this 2½ feet were seen, the rest being concealed by fallen debris.

Beds near the base of the Chalk are exposed in the cutting on the main road south of Sparsholt; they consist of tough, marly chalk, greyish-brown where damp, but drying to a light grey. I found here *Inoceramus latus, Lima globosa,* and *Rhynchonella Martini.*

Between Letcombe Regis and Letcombe Basset beds of greyish-white blocky chalk can be seen at intervals along the watercourse, especially near the latter village, where fine springs issue from beds which must be some 80 or 90 feet above the base of the Chalk. In the village of Letcombe Basset a bed of very hard siliceous chalk is seen and the same or another bed is exposed in the road-cutting on Holborn Hill, west of the village, the beds seen here being as follows:—

		ft.
Hard stony chalk (probably siliceous)	- - - - -	6
Soft crumbling grey marl	- - - - - - -	4
Tough blocky chalk	seen for	3

In the roadway south-east of the church, about 150 feet above the base, there is some rather hard and rough greyish chalk resembling Totternhoe Stone, but a sample of this was sliced and examined by Mr. W. Hill, who reports it to be an ordinary hard chalk marl, rather full of shell fragments and foraminifera, but not comparable with true Totternhoe Stone.

No good exposures were seen near Wantage, but near Manor Farm strong springs issue from blocky chalk at about the usual horizon.

The exposure of the basement beds north of Lockinge has already been mentioned (see p. 167). Beds near the base can be seen in the main road south of East Hendred and at the Broadway south of Harwell, where there are many fragments of *Am.* [*Schloenb.*] *varians* and *Am.* [*Acanth.*] *Mantelli.* Higher beds, which must be near the top of the zone, are shown in a small pit south of Arfield Farm, consisting of grey chalk weathering into platy pieces, and containing *Am. varians* and *Plicatula inflata.*

The middle and upper parts of this zone are well exposed in the railway cuttings between Upton and Chilton on the Didcot and Newbury line.

The first cutting near Upton begins at a level of about 60 feet above the base of the Chalk Marl. The beds exposed consist of firm marly chalk in which *Am.* [*Schloenb.*] *varians* is the most abundant fossil. Microscopic examination of this chalk showed it to have the ordinary characters of Chalk Marl, except that the remains of siliceous sponges, both mesh and spicules,* were present in some abundance.

In the next cutting the lowest beds are rather hard, and contain many fossils, including sponge remains; these beds pass up into marly and blocky chalk, of which there is from 16 to 20 feet, and the highest beds contain two courses of hard grey chalk. These courses are probably the lowest of those which are seen at the entrance of the next cutting east of Chilton, where the following succession can be measured:—

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* See Quart. Journ. Geol. Soc., Vol. xlv. p. 408.

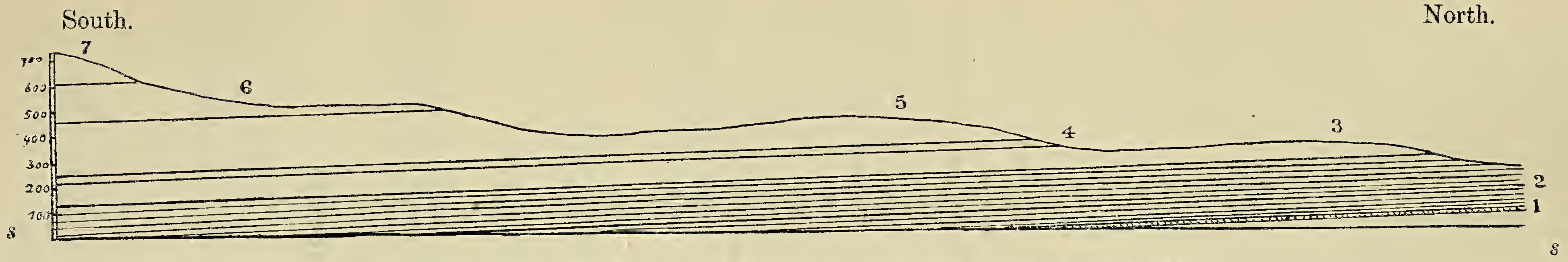

FIG. 39.—Section through the Chalk Escarpment near Wantage (Berkshire).

Horizontal Scale, two inches to a mile. Vertical Scale, 800 feet to an inch.

7. Upper Chalk.
6. Middle Chalk.
5. Lower Chalk.
4. Green Sand } Selbornian.
3. Malmstone } Selbornian.
2. Gault } Selbornian.
1. Lower Greensand.
s.s. Sea Level.

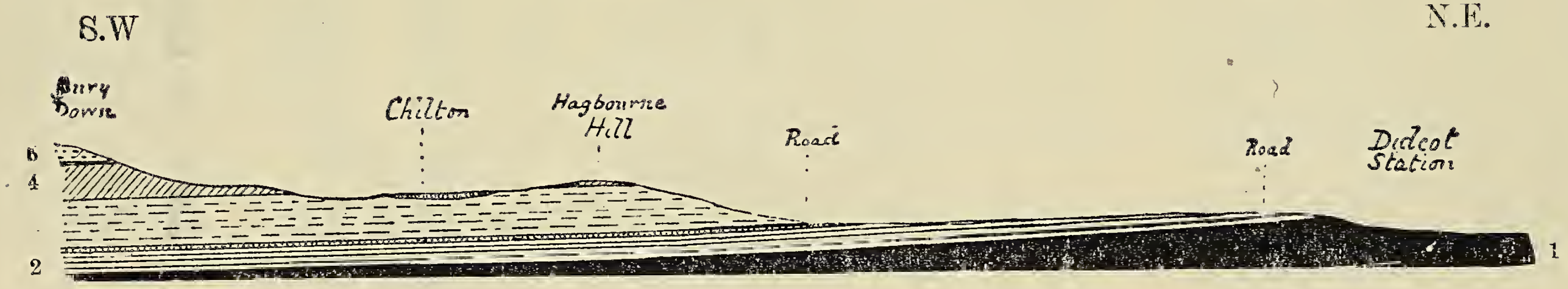

FIG. 40.—Section through Chilton and Didcot, in Berkshire.

Horizontal Scale, one inch to a mile. Vertical Scale, 1,200 feet to an inch.

5. Upper Chalk.
4. Middle Chalk.
3. Lower Chalk.
2. Upper Greensand (Sand and Malmstone).
1. Gault (Lower and Upper).
N.B.—The patch under Chilton is gravel.

		ft.	in.
Zone of *Hol. subglobosus.*	Greyish bedded chalk, rather hard	10	0
	Soft grey chalk	3	0
	Hard rocky grey chalk	1	0
	Grey chalk with shaly partings, passing down into hard grey bedded chalk	5	0
	Totternhoe Stone.—Brownish-grey stone, firm and rough to the touch, with many phosphatic nodules and fossils	2	0
Zone of *Am. varians.*	Grey chalk marl, breaking conchoidally	5	0
	Very hard compact limestone (siliceous)	1	9
	Shaly grey chalk	0	6
	Hard rough grey chalk (siliceous and containing fossils)	0	9
	Loose grey marly chalk	3	0
	Hard rough grey chalk (siliceous)	0	8
	Loose grey marly chalk	2	0
	Firm blocky chalk, seen for	3	0
		37	8

Am. [*Schloen.*] *varians* is common in all the beds below the marl which underlies the Totternhoe Stone, but does not occur in that marl nor in the stone above, except in the condition of a phosphatic cast.

All the hard courses in the Chilton section contain sponge-spicules, but these are most abundant in the highest and hardest of the beds. Some of the spicules are still siliceous, but others are replaced by calcite. All these beds also contain minute globules and aggregations of colloid silica, and the amount of this is also greater where the proportion of sponge-spicules is greater.

The cutting on the Great Western Railway by Moulsford Station exposes a good section of beds which must be about 60 feet below the Totternhoe Stone. These are:—

	ft.
Marly chalk in courses separated by layers of soft shaly marl	10
Soft grey marl with lumps of harder chalk	8
Hard rocky chalk weathering with lenticular lumps; fossils abundant	2

The fossils found here include *Am.* [*Schloenb.*] *varians, Am.* [*Acanth.*] *Mantelli, Inoceramus latus,* and *Rhynchonella Schloenbachi?*

Zone of Holaster subglobosus.

Below White Horse Hill, on the promontory known as Dragon Hill, there is a quarry open in chalk which must by its level belong to the zone of *Holaster subglobosus,* but which has an unusual character. The beds seen in 1887 were:—

	ft.
Broken chalk, with thin bands of greyish marl	5
Hard rough greyish chalk, containing *Am.* [*Hapl.*] *Austeni,* and *Am.* [*Acanth.*] *rotomagensis,* weathering into irregular lumps	6
Whiter blocky chalk with a more even fracture	8

The Belemnite Marl was just visible at the entrance to the pit at the top of Blowing Stone Hill.

Small pits have been opened in the zone of *H. subglobosus* by Sincombe Farm south of Childrey and by Childrey Warren Farm, and again in a field on the north side of Wantage Workhouse.

A good section through the beds at the top of the Lower Chalk is exposed in a quarry by Chalkhill Barn, one mile south of Lockinge; the face in 1887 showing:—

			ft.
	Soil and rubble of hard chalk - - - - - -		4
Melbourn Rock.	Hard compact bedded chalk, somewhat nodular - -		5
	Hard rough nodular chalk, with greenish matter between the lumps - - - - - -		3
Belemnite Marl.	Soft laminated argillaceous marl -	9 inches to	1
	Hard white compact chalk - -	6 inches to	1
	Thin layers of marl, 3 or 4 inches - - - - -		¼
Firm white blocky chalk		seen for	20
		About -	34

There is no hard-and-fast line between the blocky chalk and the marly layers at the base of the Belemnite band, which seem to occur as it were, in the upper few inches of this chalk. The upper marl band contained *Ostrea vesicularis* and a broken *Actinocamax.*

The marls are seen again at two localities near Chilton, the first being in a small pit near Skeleton Farm, south-east of Chilton, where the central course of hard white chalk is about 18 inches thick; the second is in a quarry on Hagbourn Hill, north of Chilton, where the following section was exposed in 1887:—

		ft.
Melbourn Rock, broken and weathered - - - - - - -		4
Lower Chalk.	Buff-coloured laminated marl - - - -	0½
	Hard whitish chalk, some parts harder and whiter than the rest - - - - - - - -	1
	Grey laminated chalk passing down into massive whitish chalk, seen for - - - - -	3

The hard white chalk yielded *Rhynchonella plicatilis, Ostrea vesicularis,* and *Aporrhais Mantelli* (cast).

In the railway cutting near Chilton, already described (see p. 168), about 20 feet of grey chalk are seen above the Totternhoe Stone, and these beds have yielded *Holaster subglobosus* and *Discoidea cylindrica.* The base of the Totternhoe Stone is well marked, but there is no clear line between it and the overlying chalk, though planes of curvilinear jointing often pass through the top of the stone and make it appear to thin and thicken irregularly.

The outcrop of the Totternhoe Stone was found again by the side of the road to Cholsey, half a mile south-east of Lollington Farm, and blocky grey chalk is seen in a pit on Lollington Hill, and also south of Aston Upthorpe.

LIST OF FOSSILS FROM THE LOWER CHALK OF BERKSHIRE.

—	Chloritic Marl.	Chalk Marl below Totternhoe Stone.	Totternhoe Stone.	Chalk above Totternhoe Stone.	Belemnite Marl
Cephalopoda.					
Ammonites [Haploceras] Austeni, *Sharpe*	–	–	–	4	–
„ [Acanth.] Mantelli, *Sow.*	–	2	–	–	–
„ [„] navicularis, *Mant.*	–	2	–	–	–
„ [„] rotomagensis, *Brongn.*	–	–	–	4	–
„ [Schloenb.] varians, *Sow.*	–	2	3	–	–
„ [„] Coupei, *Brongn.*	1	2	–	–	–
Baculites baculoides, *Mant.*	–	–	3	–	-
Scaphites æqualis, *Sow.*	–	2	–	–	
Turrilites Bergeri, *Brong.*	–	2	–	–	
„ costatus, *Lam.*	–	2	–	–	–
„ scheuchzerianus, *Bosc.*	–	2	–	–	–
„ tuberculatus, *Bosc.*	1	2	–	–	–
Nautilus deslongchampsianus, *d'Orb.*	1	2	–	–	–
„ sublævigatus ?, *d'Orb.*	1	–	–	–	–
Actinocamax plenus, *Blainv.*	–	–	–	–	5
Gasteropoda.					
Aporrhais Mantelli, *Gardn.*	–	–	–	–	5
Avellana cassis, *d'Orb.*	1	–	–	–	–
Cerithium ornatissimum, *Desh.*	–	2	–	–	–
Dentalium sp.	1	–	3	–	–
Natica sp.	1	2	–	–	–
Pleurotomaria (casts)	1	2	3	–	–
Solarium sp.	1	2	–	–	–
Lamellibranchiata.					
Cardita tenuicosta, *Sow.*	–	2	–	–	–
Inoceramus latus, *d'Orb.* non *Mant.*	–	2	–	4 ?	–
Lima aspera, *Mant.*	–	2	3	–	–
„ echinata, *Eth.*	–	–	3	–	–
„ globosa, *Sow.*	–	2	3	–	–
Ostrea vesicularis, *Lam.*	–	–	3	4	5
Pecten asper, *Lam.*	1	–	–	–	–
„ orbicularis, *Sow.*	–	2	3	–	–
„ (Neithea) quinquecostatus, *Sow.*	1	2	3	–	–
Pholadomya decussata, *Phil.*	–	–	3	–	–
Plicatula inflata, *Sow.*	1	2	3	4	–
Brachiopoda.					
Rhynchonella Martini, *Mant.*	1	–	3	–	–
„ plicatilis, *Sow.*	–	–	–	–	5
„ grasiana ? *d'Orb.*	–	2	–	–	–
„ Schloenbachi, *Dav.*	–	3	–	–	–
Terebratula biplicata, *Sow.*	1	–	–	–	–
„ semiglobosa, *Sow.*	–	–	3	–	–
Terebratulina striata, *Wahl.*	1	–	–	–	–
„ triangularis ? *Eth.*	1	–	–	–	–
Echinodermata.					
Discoidea cylindrica, *Lam.*	–	–	–	4	–
„ subuculus, *Klein*	1	–	–	–	–
Holaster subglobosus, *Leske*	–	–	–	4	–
Salenia Austeni, *Forbes*	–	–	3	–	–
Spongida.					
Strephinia convoluta, *Hinde*	–	2	–	–	–

CHAPTER XIV.

THE LOWER CHALK IN OXFORDSHIRE AND BUCKINGHAMSHIRE.

General Description.

The Lower Chalk emerges from beneath the Melbourn Rock near Spring Farm, north of Goring, and borders the alluvium of the Thames, though partly covered by gravel, for a distance of nearly five miles, as far as Crowmarsh, opposite Wallingford. Thence its outcrop trends north-east at the foot of the main chalk escarpment, and it occupies a tract which varies from one to two miles in width by Ewelme, Watlington, Aston, Chinnor, Risborough, Wendover, and Tring, which last place we shall include in the district, although it is actually in Hertfordshire.

The composition of the Lower Chalk in these counties is the same as in Berkshire, and the total thickness in Oxfordshire is about 200 feet; in Bucks, however, it is probably not more than 180 feet, and in some places it seems to be even less than this.

The zone of *Ammonites varians* (or Chalk Marl) may be 120 feet thick in Oxfordshire, but is not more than 100 feet in Bucks. It is based on a soft glauconitic marl, which appears to form a complete passage between the Chalk Marl and the underlying Greensand (see vol. 1, p. 283). A special feature of the zone in this area is the occurrence of a bed of very compact limestone, about 50 or 60 feet above its base; for this bed the name "marl-rock" has been suggested,* and it is traceable through the greater part of the district owing to the fact that strong springs are thrown out along its course because it rests on a tenacious argillaceous marl.

The zone of *Holaster subglobosus* has a thin but persistent bed of Totternhoe Stone at its base. In Oxfordshire this is only from 2 to 4 feet thick, but it becomes thicker toward the north-east, and near Tring there are sometimes two beds with 5 or 6 feet of sandy marl between them.

The chalk which forms the rest of the zone is from 70 to 80 feet thick, consisting of grey and greyish chalk in the lower part, changing in the higher part to nearly white chalk.

In Bucks a peculiar bed of rough grey chalk occurs about 30 or 35 feet above the Totternhoe Stone, which stone it much resembles in general appearance. It is locally known as "rag," is about 2½ feet thick, and contains numerous green-coated nodules, which are feebly phosphatic. A special feature in its composition is the abundance of small fish-teeth and of minute pieces of bone ; it also contains glauconite in some quantity, but in small grains. The texture of the rock is coarser than that of the chalk above and below, while the nodules consist of fine-grained chalk-marl coloured and hardened by a slight infiltration of phosphate of lime. Where this " rag " occurs it separates the grey from the white chalk.

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* The Geology of London, Vol. i. p. 59, Mem. Geol. Survey, 1889.

The subzone of *Actinocamax plenus* presents its usual Midland aspect, consisting of two layers of grey or buff-coloured marl, with a course of firm, white, compact chalk between them, the whole being seldom more than 3 feet thick.

STRATIGRAPHICAL DETAILS.

Zone of Ammonites varians.

Basement Bed.—At the base of this zone there is a soft glauconitic sandy marl like that in Berkshire, but so far as can be judged from the few exposures it is entirely without phosphatic nodules.

No exposure of this " Chloritic Marl " was observed in Oxfordshire, but surface indications and ditch sections showed a complete passage upward from the soft Greensand at the top of the Selbornian to the soft Chalk Marl above, the amount of sandy and glauconitic material gradually decreasing upward, while that of chalky matter increases.

The same conditions prevail in Buckinghamshire, and the actual passage from the " Greensand " through the glauconitic marl was seen by the roadside near Bushey Leys, south-west of Wendover, and again by the main road about a mile north of Wendover. It was more clearly exposed in 1885 in a trench opened in the park near Aston Clinton House ; this showed about 6 feet of Chalk Marl at the upper end, passing down into glauconitic marl, and thence through marly greensand into a dark greensand consisting mainly of quartz and glauconite ; no line of division and no phosphatic nodules existed, nor were any fossils observed.

Chalk Marl.—There are many small exposures of the Chalk Marl in Oxfordshire, but none of any depth.

The upper 18 feet of it were formerly seen below the Totternhoe Stone at Crowmarsh (see 178), but this pit is now overgrown. There was also a small quarry by Rumbold's Lane, about 1½ miles north of Ewelme, where about 5 feet of very hard chalk or marly limestone was seen in 1885, but Mr. Rhodes found it sloped and ploughed over in 1899. From it I obtained *Am.* [*Schl.*] *varians*, *Turrilites costatus*, *Inoceramus latus*, *Plicatula inflata*, and *Rhynchonella grasiana*. I alsoobtained *Am.* [*Acanth*] *Mantelli* and other fossils from the material thrown out of a shallow well by Clay Lane,

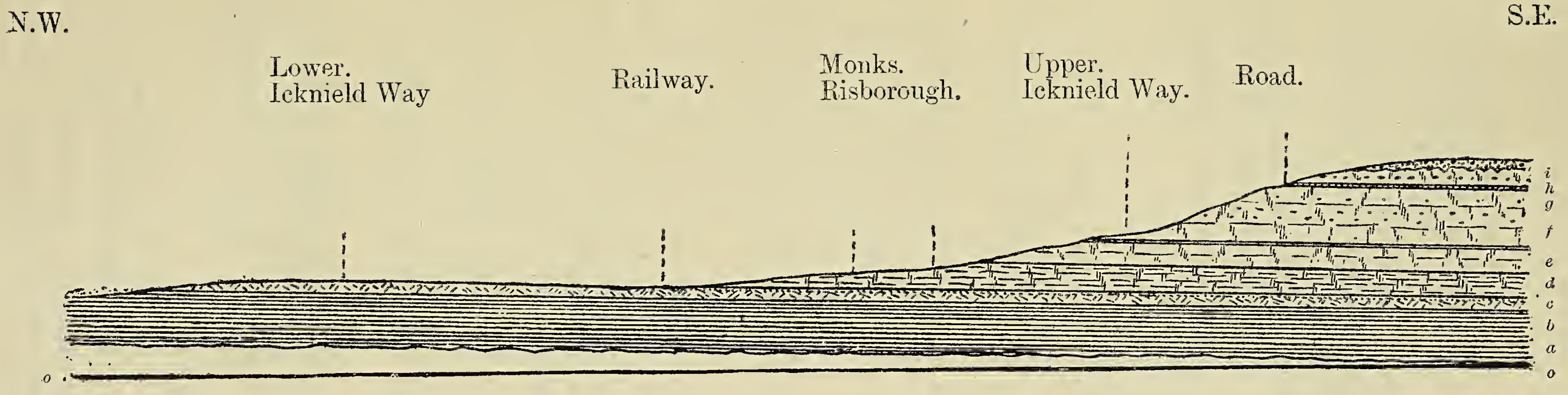

FIG. 41.—Section through the Chalk escarpment near Risborough.
Horizontal scale, three inches to a mile. Vertical scale, twice as great (880 feet to an inch).

i. Clay with flints.
h. Upper Chalk, with Chalk Rock (*g*) at its base.
f. Middle Chalk, with Melbourn Rock (*e*) at its base.
d. Zone of *Holaster subglobosus* } Lower
c. Zone of *Ammonites varians* } Chalk.
b. Greensand and Malmstone.
a. Gault clay.
o. o. Ordnance datum.

south-west of Ewelme. This was about 16 feet deep through soft broken marl into tough brownish sandy marl, with lumps or layers of hard marly limestone.

Mr. Rhodes also found a new pit open near Rumbold's Copse, which showed about 10 feet of greyish chalk, and from which he obtained *Am.* [*Schloenb.*] *varians, Pecten Beaveri, Lima echinata ?, Palæga Carteri,* and other fossils, the assemblage suggesting that of the Totternhoe Stone. The beds cannot be far from that horizon, and may be just below the stone itself.

The bed of hard "marl-rock" is visible at the spring-heads o Brightwell Uppertown and of Cuxham; and Mr. Rhodes in 1899 found that a small pit had been opened above the spring at Brightwell, which showed the following beds:—

	ft.
Grey chalk marl, much weathered - - - - - -	3
Hard marly stone, with Cyprids and other fossils - - -	1
Grey marl with hard lumps - - - - - seen for	6

The hard concretionary lumps in the lower marl are as large as a man's head, and fossils occurred in them.

Near the village of Pyrton a small pit was opened many years ago, and from this some fossils were obtained by Mr. Montague Smith, and are now in theWoodwardian Museum (see list on p.183).

The outcrop of the hard marl-rock can be seen in Shirburn Park; it weathers into a flaggy stone, and is seen again just above the fine springs which issue from beneath the main road at Lewknor.

In Buckingham also the only exposures along the main outcrop of this zone are at the spring-heads along the outcrop of the "marl-rock." At Bledlow, on the east side of the churchyard, there is a deep dell the terminal face of which is almost vertical and about 25 feet deep; strong springs here issue from a hard grey sandy chalk, with softer and more marly chalk above.

Near Risborough all the spring-heads are cleared out and utilised for the growth of watercress, some of them showing as much as 4 or 5 feet of very hard compact grey calcareous stone (with many fossils), and the use of a crowbar proved it to be underlain by soft argillaceous marl.

The outcrop of this rock-bed crosses the high road half a mile N.N.W. of Wendover, and many fossils were obtained in 1885 from a hole dug for a telegraph post, several kinds of sponges being common here, including *Plocoscyphia labrosa* and one identified by Dr. Hinde as *Phymatella intumescens.*

This hard bed has not been traced beyond Buckland, south of which it seems to thin out, or pass into a mere layer of hard lumps.

A good section of Chalk Marl about 30 feet above the base is exposed in a quarry at the west end of the outlier which forms West End Hill, near Cheddington, north of Tring. As seen in 1884 this was as follows:—

	ft.
Soil and soft flaky marl	4
Irregular lumps of hard greyish chalk in two bands, separated by soft marl	4
Blocky marl or "clunch" in irregular beds	12

Many of the characteristic fossils of the zone may be obtained from the hard lumps in this quarry (see p. 183).

A boring was made at Bulbourne, north of Tring, for the Birmingham Canal Company in 1855, and specimens are preserved at the local office of the Company at Marston. From an examination of these specimens made by me in 1884 the beds traversed by the boring seem to have been as follows:—

		ft.
Lower Chalk, 140 feet.	Soft Chalk	20
	Hard grey sandy chalk (Totternhoe Stone), samples from 25½ and 27½ feet	9
	Soft chalk marl	5
	Soft bluish marls	25
	Soft grey marl with harder lumps	10
	Grey micaceous silty marl	2
	Hard rocky chalk, with impression of *Am.* [*Schloenbachia*] *varians* at 71½ feet	? 4
	Soft grey and blue argillaceous marls	? 65
Gault, 258 feet.	Dark micaceous grey and greenish sandy marls (? Selbornian)	10
	Light grey clays	80
	Clay with phosphate nodules	1
	Gault clays	159
	Clay full of sand and pebbles	8
L.G.S.	Brown sands	62
	Greenish sand	5
		465

Both the Gault and the beds below the Totternhoe Stone are thicker than usual, but if the record is reliable, the Chalk Marl has here a thickness of 111 feet. The hard rocky bed at 71½ feet is probably one of those seen in the quarry on West End Hill, for the sample much resembles them.

Zone of Holaster subglobosus.

The Totternhoe Stone, with some of the underlying Chalk Marl and the greater part of the overlying zone, was formerly well exposed in the quarries (now overgrown) by the side of the main road on Crowmarsh Hill. As seen in 1885, the Totternhoe Stone was about 4 feet thick, forming a band of massive brownish-grey chalk which could be quarried in large blocks. At the present time the upper end of the quarry shows about 30 feet of nearly white blocky chalk, the bedding of which is obscured by the curvilinear jointing of the mass. Between the foot of this and the level on which the kiln stood there must be 35 or 40 feet of similar chalk, whitish above, but becoming grey below, and containing *Am.* [*Acanth.*] *rotomagensis*, Below the kiln the following beds were seen :—

		ft.
Zone of *H. subglobosus.*	Blocky grey chalk, with oblique jointing	6
	Hard rough brownish-grey chalk, with some fossils and many phosphatic nodules near the base (Totternhoe Stone)	4
Zone of *Am. varians.*	Hard bluish-grey marl, breaking with a semi-conchoidal fracture	8
	Dull grey sandy stone, rather hard, but splitting into shaly layers	2
	Soft grey marl without definite bedding	8
		28

The dip here is about 2° to the south-eastward. From Crowmarsh Hill the outcrop rises north-eastward, and can be found just above the 300 feet contour in Day's Lane, south of Ewelme.

The only other undoubted exposure of Totternhoe Stone seen by me in Oxfordshire was in the bank by the roadside, 160 yards south-east of Chinnor Station ; it is here about 2 feet thick, and contains the usual brown phosphatic nodules.

In Buckinghamshire there is no good section through the Totternhoe Stone, but it is exposed in many roadways ; as for instance near Winnall, south of Bledlow, and in the roadway north-east of Culverton, its thickness being a little over 3 feet. The top 2 feet were also seen in an old pit at Parkfield, south of Princes Risborough, the stone here being firm and blocky, full of phosphatic nodules, and containing a few fossils, especially *Rhynchonella mantelliana*.

At Wendover the well-head spring rises from the Totternhoe Stone, which can be seen in the watercourse, and thence it is traceable for several miles along the ground above the course of the Wendover Canal. It crosses this near Buckland, and the top part of it with *Rhynch. mantelliana* is exposed in a small pit south-east of Drayton, passing up into grey chalk.

Near Tring two beds of Totternhoe Stone have been seen, each between 2 and 3 feet thick, and separated by 5 or 6 feet of fissile sandy marl. The upper bed is more massive than the lower, which is somewhat flaggy, but both contain the usual brown phosphatic nodules.* One of these beds is exposed in the roadway south of Tring Wharf, but the quarry described by Mr. Whitaker is now filled up. It is also visible at the northern end of the long cutting on the L. and N.W. Railway.

Another exposure is in the bank of the lane south-east of Ivinghoe Aston. This is the upper bed, and consists of dark grey sandy stone (1 foot) with phosphates, and 18 inches of lighter grey stone, with many fossils overlain by light grey chalk.

Exposures of the Higher Beds.—Of the chalk above the Totternhoe Stone in Oxfordshire there was formerly a good section in the upper level of the quarry at Crowmarsh, already described

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* See Whitaker in Mem. Geol. Survey, Vol. iv. p. 40, 1872.

Part of the same zone is exposed in the limekiln quarry on Beggars bush Hill, south-west of Ewelme, the pit being about 40 feet deep, and the upper 30 feet being of whitish chalk.

The same chalk is seen in a small pit south of Lewknor, in the railway cutting south-east of that village, and in the cuttings by Aston Rowant Station, but they present no features of interest, and fossils are rare.

The very highest beds, with the subzone of *Actinocamax plenus*, are well exposed at two places near Wallingford. A quarry on White Hill, east of North Stoke, shows :—

			ft.
	Melbourn Rock - - - - - - - - - - - -		5
Bel. Marls.	Buff-coloured laminated marl, with *Act. plenus* - -		½–1
	Hard compact white chalk - - - - - - -		1–1¼
	Greenish shaly marl, *Rhynchonella sp.* -	about	⅓
	Blocky white chalk, with patches and mottlings of grey material near the top, giving it a brecciated appearance	about	10

The other section is in a deeply-cut cart-road by Coldharbour farm, east of Crowmarsh, and shows :—

			ft.
	Melbourn Rock - - - - - - -	about	3
Bel. Marls.	Soft grey laminated marl - - - - - -	„	1
	Hard white compact chalk - - - - - -	„	1
	Thin parting of grey marl.		
	Firm white chalk - - - - - - -	seen for	5

South of Bledlow, in Buckinghamshire, there is a quarry just above the outcrop of the Totternhoe Stone, showing tough greyish-white blocky chalk with large Ammonites,—*Am.* [*Acanth.*] *rotomagensis* and *Am.* [*Acanth.*] *sussexensis.*

The best section in Bucks, however, is in the large chalk pit at Butler's Cross, west of Wendover. The beds here seen are the following :—

			ft.
	Middle chalk and Melbourn Rock - - - - - - -		12
Act. plenus Beds.	Soft grey laminated marl - - - - - - -		¾–1
	Hard white compact chalk, thinning out southward -		0–1
	Soft grey shaly marl - - - - - - - -		½
	Green gritty shale, thinning out southward - -		0–1
Zone of *Holaster subglobosus.*	Hard rough chalk, mottled grey and white, passing into next - - - - - - - - - - -		1–1½
	Rather hard white chalk, breaking into massive angular blocks with smooth surfaces - - -		9
	Parting of shaly marl		
	Tough grey bedded chalk - - - - - - -		5
	Hard rough grey chalk, with grains of glauconite and many green-coated nodules - - - - -		2
	Tough grey chalk - - - -	seen for	3

The remarkable part of this section is the thinness of the white chalk at the top of the zone and the signs of erosion presented by its upper surface. Instead of the usual 30 or 40 feet of white chalk, there is here only 9 or 10 feet, and the total thickness between the Belemnite marls and the Totternhoe Stone, which crops out at the cross-roads, is only about 50 feet, instead of 75 or 80. It would appear, therefore, that some 25 or 30 feet of this white chalk has here been cut out by current erosion before or during the deposition of the overlying marl.

At the northern end of the section the Belemnite beds consist as usual of two layers of marl, with an intervening bed of white chalk; but the lower marl band is unusually thick, measuring 18 inches, and is very shaly and gritty in the lower part. When followed southward, this lower part is seen to thin out entirely, the surface of the white chalk below rising as shown in the sketch (Fig. 42). A few yards further the bed *d* also thins out, allowing the two marls to come together and form one band about 2 feet thick.

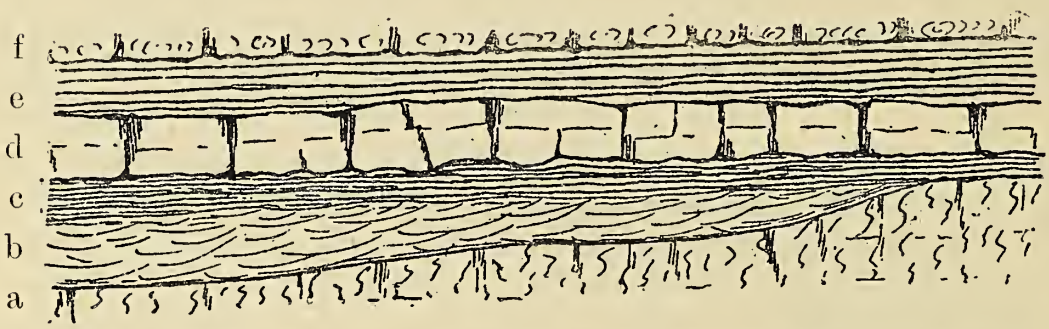

Fig. 42.—The Belemnite Beds in the chalk-pit at Butler's Cross, near Wendover.

f. Base of Melbourn Rock.	*c.* Lower marl.
e. Upper marl.	*b.* Grey-gritty shale.
d. Hard white chalk.	*a.* Mottled rock.

The upper surface of the massive chalk (*a*) is slightly undulating and very sharply marked. The uppermost 10 or 12 inches of this chalk has a curious structure, being very hard and marbled with a grey chalk, of which in some places there is more than of the white chalk, but so intimately are the two mingled that the rock breaks through both.

The nodule-bed near the base is also of special interest; the nodules are of all sizes up to that of a large potato. Internally they are of a pale buff colour, but the outer portion is riddled with small tubules which are filled with the chalky matrix; the green matter outside is merely a coating. The mass of the bed is rather coarse-grained, and under the microscope it is seen to consist chiefly of broken shell-fragments, with many glauconite grains and some Foraminifera. The material of the nodules is compact and fine-grained.

The next exposure shows only the highest beds overlain by the Melbourn Rock. This is by the main road to Tring, less than half a mile east of Buckland Wharf, and here the following beds are seen:—

		ft.
Melbourn Rock, etc. (see p. 460)		16
Lower Chalk.	Yellowish shaly marl, with lenticular lumps of hard chalk at its base	1
	Hard solid white chalk	1½
	Layer of soft grey marl	½
	Tough greyish-white blocky chalk - seen for	10

The upper part of the Lower Chalk was formerly exposed in a continuous section along the cutting of the L. and N. W. Railway north-west of Tring Station. A small synclinal flexure brings in the Belemnite Marls about a quarter of a mile north-west of the station. Below these there is about 20 feet of whitish blocky chalk, passing down into greyish chalk, and just one mile from the station a bed of hard grey sandy "rag" rises from the floor of the cutting and forms a conspicuous band on each side as it rises toward the surface, its dip being about 2°. This bed is 2 feet thick, contains many green-coated nodules, and resembles that at Butler's Cross above described. The chalk below is wet, dark grey and somewhat marly. Beyond this the face of the cutting is much obscured by fallen débris, but the Totternhoe Stone does not crop out till near the end of the cutting, about two miles from the station.

Probably the beds undulate somewhat, for if the dip was continuous the total thickness of chalk between the Totternhoe Stone and the Belemnite Marl would be double what it ought to be, and its real thickness is not likely to be more than 80 feet.

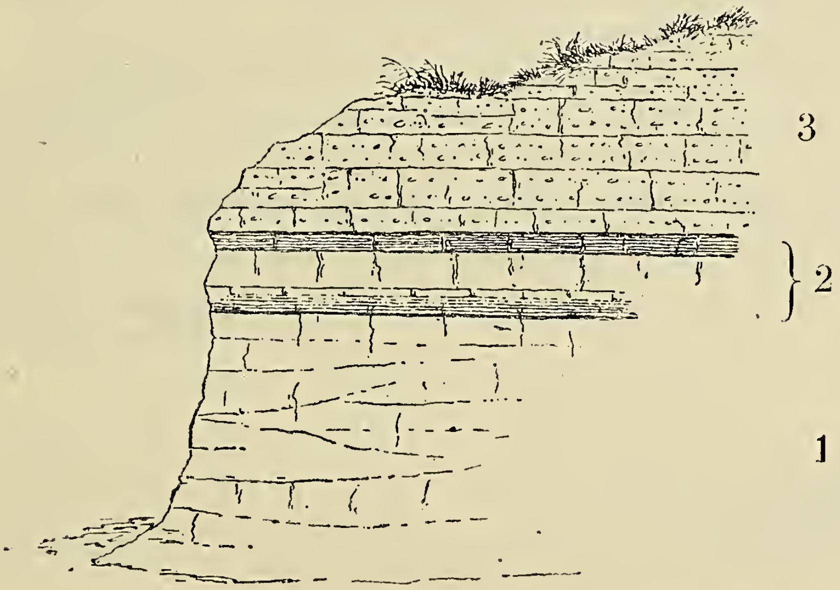

FIG 43.—Part of a Quarry at Pitstone, near Tring.

3. Melbourn Rock 2. Belemnite Beds. 1. Whitish Lower Chalk.

A quarry near Pitstone, N.E. of Tring, exposes the Belemnite Beds near the entrance, the central band of white chalk being here 2 feet thick, while the layers of marl above and below are not more than 6 inches thick; the lower one, however, yields the characteristic Belemnite (*Actinocamax plenus*). Fig. 43 is a rough sketch of this section

The "rag-bed" is again exposed in a quarry by the roadside south-east of Ivinghoe. The beds seen are:—

	ft.
Greyish-white chalk, breaking along curved planes - - -	7
Hard yellowish somewhat gritty chalk, breaking into thin even layers - - - - - - - - - - -	2
Hard grey gritty "rag" full of green grains and green-coated nodules - - - - - - - - - -	2¼
Tough greyish marly chalk - - - - - - seen for	6

FOSSILS FROM THE LOWER CHALK OF OXFORDSHIRE AND BUCKINGHAMSHIRE.

The localities for the rock-bed in the Chalk Marl are: (1) In Oxfordshire, Crowmarsh, Clay Lane (west of Ewelme), Brightwell Upper Town, Rumbold Lane (west of Brightwell), and Pyrton, near Watlington; (2) in Bucks, the railway cutting south of Risborough Station, the spring heads at Princes Risborough, Monks Risborough, and Ascot; (3) West End Hill, near Tring. The figures in this column refer to the districts as above numbered.

The localities for Totternhoe Stone are:—For Oxfordshire (*o*), Crowmarsh; in Bucks (*b*), Winnall road-cutting, near Bledlow north-east of Culverton, and at Parkfield, south of Risborough; and Ivinghoe, near Tring (indicated separately by the letter *i*).

The localities for the chalk above the Totternhoe Stone are:—In Oxfordshire (*o*), Crowmarsh; in Buckinghamshire (*b*), pits south-west of Bledlow, south-east of Saunderton, near Whiteleaf, south-east of Great Kimble, and at Butler's Cross.

The localities for the Belemnite Marls are:—In Oxfordshire (*o*) North Stoke; in Bucks (*b*), Butler's Cross.

The fossils were obtained for the Geological Survey by Mr. J. Rhodes, and identified by Messrs. Sharman and Newton, except those from Oxfordshire, which were obtained by myself, and those from West End Hill, Bucks, which include some found by Professor Barrois (see list in his Recherches, p. 151).

—	Marl Rock.	Totternhoe Stone.	Chalk above.	Belemnite Marls.
Pisces.				
Beryx - - - - - - - - - - -	—	—	o	—
Corax falcatus, *Ag* - - - - - - - - -	—	—	b	—
Scapanorhynchus raphiodon, *Ag.* - - - - - -	—	—	b	—
„ subulata, *Ag.* - - - - - - -	2	—	—	—
Protosphyræna ferox, *Leidy* - - - - - - -	—	—	b	—
Elasmobranch vertebra - - - - - - - -	—	—	—	b
Fish scales - - - - - - - - - -	3	—	b	b
Cephalopoda.				
Ammonites [Acanth.] Cunningtoni, *Sharpe* - - -	—	—	b	—
„ [Hoplites] falcatus, *Mant.* - - -	1	—	—	—
„ [Haploceras] lewesiensis, *Mant.* - -	—	—	—	b
„ [Acanth.] Mantelli, *Sow.* - - - - -	1	—	o	—
„ „ navicularis, *Mant.* - - -	1 2 3	—	—	—
„ „ rotomagensis, *d'Orb.* - -	—	b i	o b	—
„ [Schloenb.] varians, *Sow.* - - - - -	1 2 3	b	—	—
„ „ Coupei, *Brongn.* - - - -	1 2 3	—	—	—
Anisoceras armatus? *Sow.* - - - - - - -	1	—	—	—
Baculites baculoides, *Mant.* - - - - - - -	3	—	—	—
Turrilites costatus, *Sow.* - - - - - - -	1	—	—	—
„ gravesianus, *d'Orb* - - - - - -	3	—	—	—
„ Mantelli, *Mant.* - - - - - - -	2 3	—	—	—
„ tuberculatus, *Bosc.* - - - - - -	1 2	—	—	—
Actinocamax plenus, *Blainv.* - - - - - - -	—	—	—	o b
Nautilus elegans, *Sow.* - - - - - - - -	1	—	—	—
„ sp. - - - - - - - - - -	3	—	—	—

Fossils from the Lower Chalk of Oxfordshire and Buckinghamshire.—*contd.*

——	Marl Rock.	Tottern-hoe Stone.	Chalk above.	Belemnite Marl.
Gasteropoda.				
Aporrhais carinata, *Mant.*	1 2	—	—	—
Avellana cassis, *d'Orb.*	1 2 3	—	—	—
Natica vulgaris ? *Reuss*	1 2	—	—	—
Pleurotomaria sp.	—	—	—	—
Solarium sp.	2	—	—	—
Trochus or Turbo	2	o	—	—
Lamellibranchiata.				
Arca carinata, *Sow.*	1 2 3	—	—	—
Aucellina gryphæoides, *Sow.*	1	—	—	—
Cardita tenuicosta, *Sow.*	2 3	—	—	—
Hinnites (? new sp.)	1	—	—	—
Exogyra haliotoidea, *Sow.*	—	—	b	—
Inoceramus Cuvieri, *Sow.*	—	—	b	—
„ latus, *d'Orb.* non *Mant.*	1 2 3	—	b	b ?
„ mytiloides, *Sow.*	—	—	b	b
„ striatus, *Sow.*	3	—	b	—
Lima aspera, *Mant.*	1	o	b	—
„ elongata, *Sow.*	1 3	—	—	—
„ globosa, *Sow.*	1	o b i	o	—
„ echinata ? *Eth.*	1	—	—	—
Nucula sp.	3	b	—	—
Ostrea canaliculata, *Sow.*	3	—	—	—
„ normaniana, *d'Orb.*	—	—	—	b
„ vesicularis, *Lam.*	1 2 3	b i	o b	o b
Pecten Beaveri, *Sow.*	1 3	—	o b	—
„ elongatus, *Lam.*	3	i	—	—
„ orbicularis, *Sow.*	1 2 3	—	—	—
„ (Neithea) 5-costatus, *Sow.*	1 3	i	—	—
Plicatula inflata, *Sow.*	1 2 3	b	o	—
Pholadomya decussata, *Phil.*	1 3	—	—	—
Brachiopoda.				
Kingena lima, *Defr.*	—	i	—	—
Rhynchonella Cuvieri, *d'Orb.*	—	—	b	b
„ grasiana, *d'Orb.*	1 2 3	o i	—	—
„ mantelliana, *Sow.*	—	o b i	—	b ?
„ Martini, *Mant.*	2 3	—	—	—
„ plicatilis, *Sow.*	—	—	—	o b
Terebratula semiglobosa, *Sow.*	2	o b i	o b	—
„ biplicata, *Sow.*	—	i	—	—
Terebratulina striata, *Wahl.*	1 2	—	b	—
Echinodermata.				
Cidaris hirudo, *Sorig.*	—	—	—	b
Discoidea subuculus, *Klein*	1 3	—	—	—
Hemiaster Morrisi, *Forbes*	2 3	—	—	—
Holaster lævis, *de Luc*	—	—	b	—
„ subglobosus, *Leske*	—	—	o	—
„ trecensis, *Leym.*	—	—	b	b
Annelida.				
Serpula annulata, *Reuss*	—	i	—	—
„ umbonata, *Sow.*	—	i	—	—
Crustacea.				
Enoploclytia sp.	—	—	b	—
Palæga Carteri, *Woodw.*	1	—	—	—
Pollicipes glaber, *Roemer*	1 2	—	—	—
Spongida.				
Brachiolites sp.	2	—	—	—
Phymatella intumescens, *Roemer*	1 2	—	—	—
Plocoscyphia sp.	3	—	—	—

CHAPTER XV.

THE LOWER CHALK IN BEDFORDSHIRE AND HERTFORDSHIRE.

General Description.

Near Dunstable, in Bedfordshire, the Lower Chalk is about 200 feet thick, but it becomes rather thinner to the northward, and is not more than 170 feet between Hitchin and Ashwell, in Herts.

Near Dunstable there are passage beds between the Upper Gault and the Chalk Marl, but throughout the rest of the area included in these counties the base of the Chalk Marl is marked by a layer of phosphate nodules (Cambridge Greensand) resting on an eroded surface of Gault.

The zone of *Ammonites varians* is about 80 feet thick near Totternhoe, and appears to consist throughout of soft marly chalk.

The zone of *Holaster subglobosus* has at its base a conspicuous bed of Totternhoe Stone, which is sometimes 20 feet thick as at Totternhoe, sometimes divided into two beds by an intervening band of marl, as near Hitchin.

The rest of this zone seems to be about 100 feet thick near Dunstable, but is not more than 80 feet near Hitchin and Baldock. It consists of grey chalk in the lower part and of nearly white chalk in the upper half. There is occasionally a bed of hard grey rag with large brown and yellow nodules, but it seems to be on a higher horizon than that near Tring.

The subzone of *Actinocamax plenus* presents no unusual features except that the central hard white chalk is sometimes replaced by brecciated grey and white chalk.

Stratigraphical Details.

1. Zone of Ammonites varians.

Chloritic Marl and Coprolite Bed.—At Eddlesborough and Eaton Bray, on the border of Bucks, the Chalk Marl passes down through soft glauconitic marl into the Selbornian sands (see Vol. I.); and greenish micaceous sand, with presumably the same upward passage into Chalk Marl, can be traced around the low-lying ground between Totternhoe and Tilsworth. East of this the Cretaceous strata are concealed by Glacial deposits, and the base of the Chalk has not been observed.

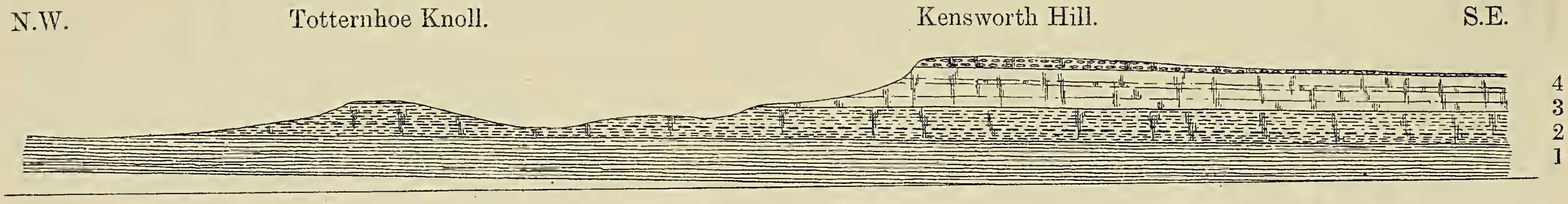

FIG 44.—Section through Totternhoe Knoll and Dunstable Downs.

Horizontal Scale $1\frac{1}{3}$ inches to a mile. Vertical Scale 800 feet to 1 inch.

4. Upper Chalk
3. Middle Chalk.
2. Lower Chalk.
1. Gault (Upper and Lower).

The "Coprolite-bed," or Cambridge Greensand, sets in near Harlington, and was worked in 1874 between the villages of Sharpenhoe and Barton. The following account of the section exposed in a working near Sharpenhoe is quoted from my paper on the "Relations of the Gault and Cambridge Greensand."*

The beds then seen were as follow:—

Chalk Marl.	Greyish-white marl - - - - - -	[illegible]
	Greenish-grey marl, with a few buff-coloured phosphatic nodules - - - - - - -	4
	Bluish argillaceous marl- - - - - -	2
	Bluish-grey sandy clay, with green grains, many nodules and fossils - - - - - -	1
Gault—Blue Clay below.		

The nodule-bed is "the representative of the Cambridge Greensand, but its appearance is very different. There is less sand and glauconite, and most of the coprolites are formed of a lighter coloured phosphate, though some are of the usual black colour; These latter, however, have not been subjected to the same amount of rolling as those in Cambridgeshire, the small *Ostreæ* and *Plicatulæ* upon them being in much better preservation, and fine striations being visible on the latter which I have never seen before."

The inference from these facts was that these phosphate nodules had not travelled so far, but were nearer their original source than those of Cambridgeshire; this source being the Upper Gault marls which still exist in Buckinghamshire and extend a short distance into Bedfordshire, but are cut out by erosion toward the northeast, though they may extend below the Chalk to the eastward between Hitchin and Ware.

Coprolites were also largely dug by Higham Gobion and Shillington between the years 1868 and 1875, and again at Arlesey, north of Hitchin, where the following notes were taken by Mr. Whitaker at the Arlesey Cement Works in 1868:—

> The Chalk Marl, 8 to 12 feet, passes down into marly clay with green grains and dark nodules. At one part the green grains occur up to 4 feet above the Gault, but in the weathered part of the section the junction bed appears as a pale green layer of 2½ feet, the nodules being chiefly in the bottom part, a layer resting on the Gault. The Gault is exposed for 10 or 12 feet, and the junction is well marked, with a very slight southerly dip.

Writing of the pits which were opened near Ashwell and Morden between 1866 and 1874, Mr. H. G. Fordham says†—"The bed [*i.e.* Cambridge Greensand] is from 18 inches to 3½ feet in thickness, and varies considerably in the proportion of nodules. It graduates into the Chalk Marl above, the glauconite grains extending higher than the nodules, and the nodules being more abundant in the lower part of the bed."

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* Quart. Journ. Geol. Soc., 1875, Vol. xxxi. p. 262.

Proc. Geol. Assoc., Vol. iv. (1878), p. 150.

Fossils are not so abundant in this district as they are in the coprolite pits near Cambridge, and though Mr. Fordham collected carefully for many years, he only obtained about forty species of Invertebrates and seven or eight species of Vertebrate remains.

A fuller account of the Cambridge nodule-bed will be given in the next chapter, but it may be observed that the nodules which were dug near Shillington, Arlesey, and Ashwell were mostly black, and have clearly been derived from the Gault. The common and characteristic species are such as are found in the Gault nodule-beds of Buckinghamshire and in the Upper Gault of Folkestone; while the fossils which characterise the Chloritic Marl and Rye Hill sand of Wiltshire and other southern counties, such as *Am.* [*Schl.*] *varians, Am.* [*Acanth.*] *Mantelli, Pecten asper, Cucullæa mailleana,* and *Terebratella pectità,* have never been found among these Bedford and Cambridge "coprolites."

Chalk Marl.—The thickness of the zone of *Ammonites varians* appears to be about 80 feet. The lower part is a dark grey marl, sandy near the base, drying light grey; the higher part is a grey or bluish-grey calcareous marl, with little sand, but mixed with fine argillaceous matter in variable quantity. No beds of hard limestone have been seen in this district, but some hard calcareous nodules occur in the railway cutting near Charlton, north-east of Dunstable. These concretions are heavy and compact, resembling septaria in having cracks filled with calc-spar; some of them are a foot in diameter. They occur in two layers, which dip southward, and lie about 40 feet below the Totternhoe Stone, which is seen further on in the cutting. They are embedded in soft grey marl, which passes up into a bluish-grey marl below the Totternhoe Stone.

Zone of Holaster subglobosus.

Totternhoe Stone.—This stone attains its maximum thickness, 20 to 22 feet, in the counties of Bedford and Hertford. It has been quarried in many places as a building-stone from very early times, and it is also a source of water-supply, many strong springs occurring along the line of its outcrop, and giving rise to small permanent brooks, by the side of which most of the villages are situate. Its outcrop generally forms a slight rise or low escarpment, for, being firm and blocky, it resists denudation better than the soft underlying marl. An account of its minute structure will be given in Chapter XXIV.

The bold spur which juts out from the Dunstable plateau and is crowned by the fine tumulus of "Totternhoe" (see Fig. 44) is pierced by numerous galleries driven in olden times to win the stone which crops out round the hill, but the only open section is a quarry on the northern side, and when stone is being quarried the following beds may be seen:—

		ft.
	Firm greyish-white chalk	5
Totternhoe Stone.	Firm grey sandy stone in thick beds	9
	Hard brownish stone in two massive beds	8
	Similar stone in three courses, with many phosphatic nodules at the base	5
	Soft marl said to lie below.	

The middle beds are those usually quarried, and they are traversed by wide vertical joints, into which the hand can be thrust, and by which the mass is broken up into large blocks weighing from two to three tons apiece. All the beds contain the characteristic bits of brown phosphate, but the upper beds are less hard, and flake off more easily under the action of weather and frost. The upper surface of the stone is fairly well marked.

Totternhoe Stone is exposed in the cutting on the Midland Railway near Charlton, and in a small quarry above the cutting on the eastern side.

The next complete section through the stone-beds is in the large quarry at Arlesey, north of Hitchin and south-west of the County Lunatic Asylum. The section seen here in 1884 was as follows:—

		ft.
	Soil and chalk rubble	3
Totternhoe Beds.	Hard brownish-grey stone in thick beds, with many fossils	10
	Greyish marly chalk, including a band of very soft marl	6
	Very hard sandy stone, with green-coated nodules (phosphatic) as large as walnuts	1½
	Soft grey sandy chalk, passing into soft grey marl	6½
		27

The nodule bed at the base of the stone is a marked feature in this section, and is found again in Cambridgeshire. Subsequent excavations here (during 1886 and 1887) showed the base of the Totternhoe Beds for 110 yards inclined towards the north-west at about 7°. The soft grey marl below was proved to be 20 feet thick at the south-east end of this section, and underlain by pale bluish marl, while at the north-west end only 7 feet of grey marl intervene between the Totternhoe Stone and the blue marl, the surface of the latter being nearly level. Hence there appears to have been erosion of the grey marl before the deposition of the Totternhoe Stone, resulting in the formation of a trough, which was filled up by the Totternhoe Beds.

Chalk above the Totternhoe Stone.—The workable stone generally passes up into light grey chalk, of which there is usually about 35 or 40 feet; the grey passes into a nearly pure white chalk, the change often taking place in the space of 9 or 10 inches, and this white chalk has a different microscopical structure from the greyer chalk below (see p. 304). In Bedford and Herts the thickness of this white chalk does not vary so much as it does in Bucks; it is usually from 20 to 25 feet thick, and there is often a passage at the top into the grey marly chalk of the overlying zone.

The large quarry at Totternhoe showed a good section of this zone in 1886. In the eastern pit where the Totternhoe Stone is quarried the overlying chalk is very light coloured, but this is probably due to its being near the surface, and consequently drier, for in the higher western quarry the lowest chalk is decidedly grey, though the outcrop of the Totternhoe Stone cannot be far below the floor of this pit. Of this grey chalk there seems to be about 30 feet, and it is succeeded abruptly by much whiter chalk, of which there is at least 20 feet. For these particulars I am indebted to Mr. W. Hill, who visited the place after I had seen it, and measured the thickness of the grey and white chalk. He saw it again in 1898, and found the quarry much enlarged. He noticed a layer of yellowish nodules in the face of the pit at or near the junction of the grey and white chalk. There is a decided dip to the south-east, but it was difficult to estimate the angle.

The chalk of this zone is also fairly well exposed in the deep railway cutting near Sewell, and in the cutting for the main road north-west of Dunstable.

The quarry near Leagrave, by the railway, two miles north-west of Luton, shows about 20 feet of whitish blocky chalk below the Belemnite marls; this being damp looks less white than that at Totternhoe, but it dries to the same tint.

Another pit about a mile from the above on the road from Leagrave to Sundon exposes one of the curious nodule beds which occur in this zone, the section being:—

	ft.
Weathered chalk, greyish and gritty	2
Hard yellowish flaggy chalk, with some yellow nodules	2½
Hard grey sandy "rag" with green grains and many nodules, some brown and green-coated, others large and pale yellow inside and out	1
Tough grey marly chalk - seen for	1

It will be noticed that this succession is very like that at Ivinghoe, near Tring (see p. 181), but the Sundon pit seems rather nearer the top of the Lower Chalk. It is just possible, however, that it is the same bed, and that there is a less thickness of white chalk above, due to local erosion, as at Butler's Cross, in Bucks (see p. 180).

At Hitchin the upper part of the zone is exposed in the large quarry by Grove Mill. The Belemnite marls are seen at the top, and there is about 30 feet of blocky chalk below, 25 feet of this being white and the lowest 15 grey, the change taking place through a few inches of streaky grey and white chalk. The complete section is given on p. 200, and is one of the best in the county.

The Totternhoe Stone, with from 30 to 35 feet of the overlying grey chalk, may be seen in a quarry nearly a mile west of Ashwell, where the stone was formerly quarried. Some fossils have been obtained here by Mr. H. G. Fordham.

The top of the zone is again seen in a quarry three-quarters of a mile S.S.E. of Litlington Church. The section is given on p. 199, and it is noteworthy that about 6 feet from the top there is a layer of hard gritty chalk with green grains and green-coated nodules, very like the bed at Sundon, and certainly at a higher horizon than the Ivinghoe Rag, for there are no signs of erosion here.

Belemnite Beds.—These beds are exposed in many of the quarries and sections where the Melbourn Rock is seen; as, for instance, in the quarry by the railway south-east of Leagrave, near Luton, which shows:—

		ft.
Melbourn Rock		8
Belemnite Beds.	Yellowish-grey shale, with a few nodules of hard chalk	1
	Hard compact white chalk	2
	Thin layer of grey shale (2 inches)	—
Blocky whitish chalk, streaked with grey in the upper two feet	seen for	22

The central bed of white chalk is here unusally thick, and the lower marl thinner than usual.

One of the best sections of the upper part of the Lower Chalk, including the Belemnite band and the base of the Melbourn Rock, is exposed in the large quarry by Grove Mill, one mile south-east of Hitchin. This has been cut back considerably since the writer saw it, and he is indebted to Mr. W. Hill for the following account of the section now visible:—

		ft.	in.
Soil and rubble		1	0
Hard rough white chalk (base of Melbourn Rock)		2	0
Belemnite Beds.	Irregular bed of buff-coloured laminated marl, with lenticular courses of hard whitish chalk	1	3
	Hard smooth white chalk	1	10
	Grey laminated marl	0	4
Zone of *H. subglobosus.*	Smooth blocky greyish-white chalk	1	6
	Thin marly layer	0	3
	Thick-bedded whitish chalk	25	0
	Pale grey chalk, in thick beds	15	0

At the spot where these measurements were taken the lower marl-bed is very thin, but a few yards to the eastward it thickens and becomes a well-marked bed. About 20 feet below this marl there is a band of brown-stained chalk, which extends for some distance, but dies out to the southward. Above it is a thin seam of brownish clay washed in from the surface.

Another good section is in a quarry west of Willbury Hill, near Hitchin, where the lower marl has its ordinary thickness of 10 or 12 inches, and the zone as a whole is 3½ feet thick. It was also exposed when the cutting on the Great Northern Railway at Cadwell was being widened in 1885, and here the compact white chalk is replaced by "marbled chalk," greyish with included lumps of white: fossils are very abundant in this bed, especially *Terebratulæ, Rhynchonella plicatilis, Ostrea vesicularis,* and *Actinocamax plenus,* but are almost all broken. The upper marl is also thicker and more calcareous than usual, the three beds having a united thickness of 4½ feet.

The Belemnite marls are again to be seen in the chalk-pit at Ashwell, but do not present any features of a special character, except that the lower bed is a greenish-grey marly chalk passing down into rather rough white chalk.

LIST OF FOSSILS FROM THE LOWER CHALK OF BEDFORDSHIRE AND HERTFORDSHIRE.

In the following list the localities are indicated by letters in each column, and these localities are :—

Bedfordshire.	Totternhoe quarries (t).
	The railway cutting at Chalton, north of Luton (c).
	The quarry by the railway near Leagrave (l)
	A quarry south-west of Sundon (s).
Herts.	The quarries at Arlesey, near Hitchin (a).
	The other quarries near Hitchin (h).
	The quarry at Ashwell (w).

The fossils from Chalton cutting were collected by Mr. J. Saunders, of Luton, and were named by me. (See his paper in Geol. Mag., Dec. 3, Vol. VII., p. 126, 1890.)

Those from Arlesey and other quarries near Hitchin are in the collection of Mr. W. Hill, and most of them were identified by me, but the fish have been examined and named by Mr. E. T. Newton.

Those from the other localities were principally collected by Mr. J. Rhodes for the Geological Survey, and were named by Messrs. Sharman and Newton.

—	Varians Zone.	Totternhoe Stone.	Chalk above Tot. stone.	A. plenus Sub-zone
Reptilia.				
Ichthyosaurus campylodon, *Carter*	c	—	—	—
Iguanodon Hilli, *Newton*	—	a	—	—
Polyptychodon interruptus, *Owen*	—	—	h	—
Pisces.				
Beryx (whole fish)	—	a	—	—
Cimolichthys striatus? *Ag.*	—	t	—	—
Dercetis elongatus, *Ag.* (whole fish)	—	a	s h	—
Edaphodon, sp.	—	—	h	—
Lamna appendiculata, *Ag.*	c	t c a	t s c	—
Macropoma sp. (fish and coprolites)	—	t a	—	—
Notidanus microdon, *Ag.*	—	—	t	—
Oxyrhina Mantelli, *Ag.*	—	—	s c	—
„ sp.	—	t	t	—
Protosphyræna ferox, *Leidy*	—	a	—	—
Ptychodus decurrens, *Ag.*	—	—	t s	l
Scapanorhynchus subulatus, *Ag.*	—	t	t	—
Tomognathus mordax, *Dixon*	—	—	h	—
Fish remains and coprolites	—	t c a	t s h	—
Cephalopoda.				
Ammonites [Haploceras] Austeni, *Sharpe*	—	—	t s	—
„ [Acanth.] cenomanensis, *d'Arch.*	—	a	t	—
„ [„] Mantelli, *Sow.*	a	—	—	—
„ [„] navicularis, *Mant.*	—	a	—	—
„ [„] rotomagensis, *d'Orb.*	a	a	—	—
„ [Schloenb.] varians, *Sow.*	c a	—	—	—
„ [„] Coupei, *Brongn.*	c a	t	—	—
Baculites baculoides, *Mant.*	—	—	—	—
Scaphites æqualis, *Sow.*	c	—	—	—
Turrilites gravesianus, *d'Orb.*	—	—	—	—
„ Mantelli, *Sharpe*	c a	—	—	—
„ scheuchzerianus, *d'Orb.*	—	c a	—	—
Actinocamax lanceolatus, *Sow.*	—	t c a	—	—
„ plenus, *Blainv.*	—	—	s	l h w
Nautilus atlas ? *Whit.*	—	—	t	—
„ elegans, *Sow.*	—	c	t c	—
„ sp.	a	—	—	—

LIST OF FOSSILS FROM THE LOWER CHALK OF BEDFORDSHIRE AND HERTFORDSHIRE.

—	Varians. Zone.	Tottern-hoe Stone.	Chalk above Tot. stone.	A. Plenus Sub-zone
Gasteropoda.				
Aporrhais subtuberculata, *Gard.*	c	—	—	—
Avellana cassis, *d'Orb.*	—	a	—	—
Cerithium ornatissimum, *Desh.*	—	a	—	—
Dentalium sp.	—	c	c	—
Fusus ?	—	a	—	—
Pleurotomaria brongniartiana, *d'Orb.*	c	a	t	—
,, sp. (elevated)	—	a	—	—
Trochus sp. (cast)	—	a	—	—
Lamellibranchiata.				
Arca carinata ? *Sow.*	—	a	—	—
Anomia papyracea, *d'Orb.*	a	a	—	—
Avicula sp. (new)	—	t c a	—	—
Exogyra haliotoidea, *Sow.*	—	a	—	h ?
Inoceramus latus, *d'Orb.* non *Mant.*	c a	a	t	—
,, mytiloides ? *Sow.*	—	—	t	—
Lima aspera, *Mant.*	c	a	—	—
,, echinata, *Eth.*	—	a	c	—
,, globosa, *Sow.*	c	t c a	t	—
,, new sp	—	a	—	—
Ostrea frons, *Park.*	—	a	—	—
,, cf. semiplana, *Sow*	—	—	t	—
,, vesicularis, *Lam.*	c	t c a	t s c h	l h w
Pecten Beaveri, *Sow.*	—	c a	t h	—
,, arlesiensis, *Woods.*	—	a	—	—
,, dubrisiensis, *Woods.*	—	—	h	—
,, elongatus, *Lam.*	—	t a	—	—
,, fissicosta, *Eth.*	—	c a	—	—
,, orbicularis, *Sow.*	c	t c a	h	—
,, sp. (many close set ribs)	—	a	—	—
,, (Neithea) quinquecostatus, *Sow.*	c	t a	c	—
Plicatula inflata, *Sow.*	c	t c a	t s c	—
Pholadomya decussata, *Phil.*	—	a	—	—
Spondylus striatus, *Sow.*	—	a	—	—
Teredo amphisbæna, *Sow.*	—	a	h	—
Brachiopoda.				
Kingena lima, *Defr.*	—	t a	h	—
Rhynchonella Cuvieri ? *d'Orb.*	—	—	s c	l
,, grasiana, *d'Orb.*	c	t c a	—	—
,, mantelliana, *Sow.*	c	t c a	s c h	—
,, Martini, *Mant.*	c	a	—	—
,, plicatilis, *Sow.*	—	—	s	l h w
Terebratula biplicata, *Sow.*	c	a	—	h
,, squamosa, *Mant.*	—	a	—	—
,, semiglobosa *Sow.*	c	t c a	t c h	h
,, sulcifera, *Morris*	—	—	h	—
Terebratulina striata, *Wahl.*	c	a	c	—
Crustacea.				
Enoploclytia sussexiensis, *Mant.*	—	t a	t	—
Glyphæa cretacea ? *McCoy*	—	a	—	—
Palæga Carteri, *Woodw.*	c	c	—	—
Pollicipes glaber, *Roemer*		t c a	—	—
Scalpellum sp.	—	—	—	
Annelida.				
Serpula annulata, *Reuss.*	—	t c a	—	—
,, umbonata, *Sow.*	—	t a	—	—
Echinodermata.				
Astrogonium Smithiæ, *Forbes*	—	—	h	—
Discoidea cylindrica, *Lam.*	—	—	h	—
Hemiaster Morrisi ? *Forbes*	—	t a	t	—
Holaster subglobosus, *Leske*	—	—	h	—
,, trecensis, *Leym.*	—	—	t h	—
Pentacrinus Fittoni, *Ag.*	—	—	c	—
Brachiolites sp	c	—	—	—

CHAPTER XVI.

THE LOWER CHALK IN CAMBRIDGE AND SUFFOLK.

General Description.

The thickness of the Lower Chalk in Cambridgeshire is between 160 and 170 feet, but owing to the low elevation and undulating character of the ground it covers a considerable area ; there are also several outlying tracts of it on the north-western side of the Cam valley.

The Zone of Ammonites varians, or Chalk Marl, has the Cambridge Greensand, or " Coprolite Bed," at its base throughout the county. This passes up into soft bluish-grey marl, succeeded by firmer blocky marl, or " clunch," as it is locally termed ; the complete thickness of the zone being from 60 to 70 feet. Whether this bed is the precise equivalent of the Chloritic Marl of the South of England is difficult to say, because neither *Stauronema Carteri* nor *Turrilites Morrisi* have yet been found in it.

The Totternhoe Stone continues in full force all across the county, and has been quarried in many places for building-stone. It varies in thickness from 12 to 20 feet, and its outcrop forms a distinct feature or rise in the ground.

The rest of the zone of *Holaster subglobosus* is about 80 feet thick. As in the other counties north of the Thames, it consists of greyish chalk in the lower part and nearly white chalk in the upper part, the change from one to the other being rapid. The whole consists of blocky chalk with curvilinear jointing, and without any clear bedding planes. The Belemnite Marls at the summit exhibit the usual Midland aspect, consisting of layers of marl with an intervening course of white chalk.

Stratigraphical Details.

The Cambridge Greensand, or **Coprolite Bed.**

This lies at the base of the Chalk Marl, and rests on an uneven and eroded surface of the Gault. A full account of this bed and its contents is given on the memoir on the " Neighbourhood of Cambridge," * to which the reader is referred for details, only a résumé of the more important points being here given.

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* Geology of the Neighbourhood of Cambridge, Mem. Geol. Survey 1880, by W. H. Penning and A. J. Jukes-Browne.

As an instance of the irregularity of the surface on which the base of the Chalk rests near Cambridge, Fig. 45 is reproduced from p. 37 of the memoir above quoted. The broken line shows the former continuation of the basement bed before the general detrition of the country had been carried to the present stage. The summits of the Gault ridges are, in fact, truncated by the present surface of the ground, and when the district was worked for "coprolites" these small inliers of Gault land formed what the workmen termed "patches of dead ground" within the productive area.

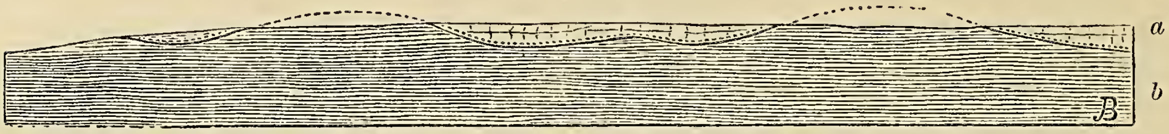

Fig. 45.—Section across the fields N.E. of Haslingfield.

Scale horizontal and vertical 300 feet to an inch.

a. Chalk-marl and coprolite-bed. *b.* Gault.

The broken line shows the former continuation of the coprolite-bed.

Smaller rolls could often be seen in the trenches of the coprolite workings, forming ridges which sometimes rose to a height of 5 or 6 feet above the intervening hollows (see Fig. 46).

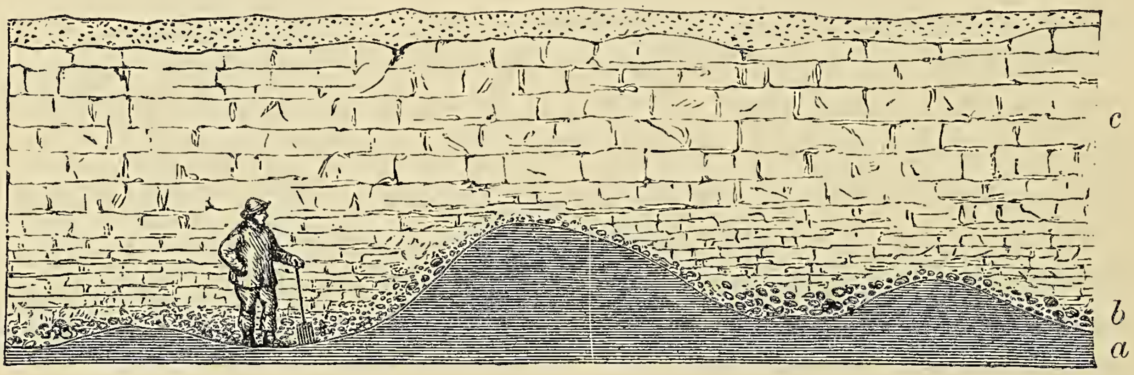

Fig 46.—View of a coprolite pit near Horningsea. (now closed)

a. Gault. *b.* Cambridge Greensand. *c.* Chalk Marl.

The matrix of the Cambridge Greensand is a green sandy marl, the sand consisting principally of glauconite grains with a small number of minute quartz grains. The proportion of sandy matter is greatest at the base, the bottom 5 or 6 inches of the deposit often having more glauconite than marl; upwards the green grains rapidly decrease in number, and generally disappear at a height of from 2 to 3 feet above the base.

The phosphatic nodules or "coprolites" are thickly crowded in the lower part of this glauconitic marl, a few scattered nodules occurring in the higher part, but not reaching so high as the green grains do. The usual thickness of the nodule-bed, as distinguished from the Greensand, is 8 or 9 inches, but in some of the hollows and troughs it reaches a thickness of 12 inches, or even more.

The nodules themselves are mostly very dark brown or nearly black, but are internally of a light brown or buff colour; amongst them, however, are some few of a dull buff colour both inside and outside. A good aggregate sample of Cambridge "coprolites" contains about 57 or 58 per cent. of tribasic phosphate of lime, with 11 or 12 per cent. of carbonate of lime and from 13 to 15 per cent. of silicates (clay, glauconite, etc.); variable amounts of sulphate and fluoride of lime are also present. The following is the composition of a sample calculated from an analysis by Professor A. Voelcker, assuming that the amount of fluorine present was 1·50 per cent., for in the analysis it was not separated from the sulphuric acid*:—

Moisture and organic matter - - - - - - -	4·01
Phosphate of lime - - - - - - - -	58·39
Carbonate of lime - - - - - - - -	11·66
Sulphate of lime - - - - - - - -	7·65
Fluoride of lime - - - - -	3·07
Silicates (clay, glauconite, etc.) - - - - - -	15·20
	99·98

Many of the nodules are simply casts of different kinds of Mollusca, Echinoderma, Crustacea, and Corals, with more or less of the calcareous test adhering. Among the others phosphatised casts of siliceous sponges (*Ventriculites* and others) are common, and many of the comparatively amorphous nodules appear to be really phosphatised sponges.† True coprolites or the exuviæ of fish and reptiles occur occasionally, but are rare, and always of a bright brown colour. Many of the nodules are covered with the attached valves of small Oysters and *Plicatulæ*, showing that they lay for a long time on the sea-floor.

The phosphatised fossils are all of species which occur in the Gault of England and France, except a few which have not yet been found elsewhere, and the most common and characteristic species, such as the *Am.* [*Schlœnb.*] *rostratus*, *Am.* [*Hoplites*] *auritus*, *Am.* [*Hopl.*] *splendens*, are forms which specially characterise the upper and middle portions of the Gault in those areas where the so-called Upper Greensand is slenderly developed.

Finally, the nodule-bed which occurs at the base of the Upper Gault of Bucks (described in Vol. I.) contains similar nodules and the same assemblage of common fossils as those of the Cambridge Greensand. Hence both the stratigraphical and the palæontological evidence lead unmistakably to the conclusion that the nodules of the Cambridge bed have been derived from the Gault, and principally from beds of Upper Gault like the upper marls of Buckinghamshire, which we may reasonably suppose originally extended northwards and eastwards over the whole area that is now occupied by the Cambridge Greensand.

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* Prof. Voelcker states that the amount of calcium fluoride is generally 3 or 4 per cent., and that in many commercial analyses it is precipitated with the phosphate of lime.

† See Prof. Sollas in Quart. Journ. Geol. Soc., Vol. xxix. p. 76 (1873).

Besides the phosphatic nodules other foreign bodies occur here and there in the shape of detached rock-fragments, which are sometimes of considerable size. They include pieces of red and purple sandstone resembling those of Devonian and Old Red Sandstone age, others of grey sandstone like Carboniferous sandstones, of soft schist and hard grey slate, of quartzite and hornstone, with many varieties of igneous rocks—granite, quartz-porphyry, basalt, hyperite, and obsidian.

Some of the softer rocks are waterworn, but the great majority are angular, and some are remarkably so, resembling the angular blocks of a glacier moraine. They vary in size from a mere pebble up to a block measuring 14 × 12 × 6 inches. Oysters, *Plicatulæ*, and phosphatic nodules are attached to their surfaces, and some at any rate seem to have been dropped in the Gault mud when the phosphates were being formed.* The source from which they were derived will be discussed in a later chapter.

Besides the derived fossils, there are a certain number of contemporaneous species in an ordinary state of preservation. A list of these is given at the end of the Chapter.

The main outcrop of the Cambridge Greensand follows very closely the line of the valleys of the Rhee and Cam to a point nearly opposite Waterbeach, where it passes beneath the Fenland. It has, however, been worked out beneath the alluvial deposits of Swaffham, Burwell, and Soham Fens, the most easterly pits observed when the area was surveyed being about two miles north-east of Soham. There can be little doubt that it continues beneath Mildenhall and Lakenheath Fens, but how far the nodule-bed extends is at present unknown.

The Chalk Marl.

The lower part of the Chalk Marl or zone of *Ammonites varians* is generally a lumpy bluish-grey marl, somewhat argillaceous, but containing from 60 to 70 per cent. of carbonate of lime. (See analyses in Chapter xxii.) The higher part is a blocky and marly chalk, probably containing over 80 per cent. of carbonate of lime.

The lower beds have been exposed from time to time in the numerous "coprolite pits," and good sections can still be seen in the trenches opened to obtain material for the Cement Works at Shepreth, Barrington, and other places south-west of Cambridge. Besides these there are few permanent exposures of the Chalk Marl. One of the best is in a quarry south-east of Kingston, which is not far above the base, and shows about 20 feet, with two definite beds of grey sandy chalk, an unusual occurrence: the section seen here in 1876 being:—

---

* Mr. H. Woods has recorded (Geol. Mag., Dec. 4, Vol. ii. p. 377) the occurrence of two angular boulders of coarse-grained quartzite in the nodule-bed at the base of the Upper Gault at Stanbridge, in Bedfordshire, and smaller stones have been found in the Gault at Barnwell, near Cambridge.

	ft.
Rubbly chalk - - - - - - - - - -	5
Grey sandy chalk - - - - - - - - -	$1\frac{1}{2}$
Rubbly chalk marl - - - - - - - -	3
Grey sandy chalk - - - - - - - - -	$1\frac{1}{2}$
Hard blocky chalk marl - - - - - - - -	10

The middle beds of the Chalk Marl are exposed in a quarry half a mile W.S.W. of Harlton, and consist of loose greyish marl containing *Rhynchonella Martini* and other small Brachiopods.

The highest beds are well seen in the large quarries near Reach. About 30 feet are shown here, the higher part consisting of tough blocky greyish-white marly chalk, passing down into softer and darker grey marl, and finally into bluish shaly marl, of which 3 or 4 feet are seen; these lower beds are full of fossils, and *Inoceramus latus* (d'Orb.) is common throughout.

The position of these quarries and the undulation of the beds which brings in the small tracts of Totternhoe Stone at Reach and Burwell are shown in Fig. 47:

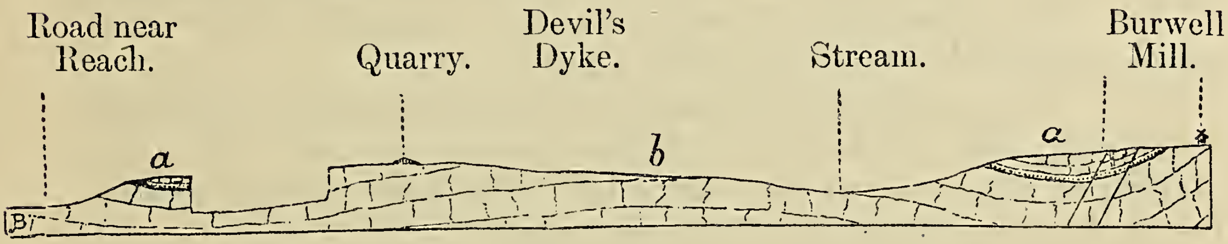

FIG. 47. Diagram-section from Reach to Burwell.

Horizontal Scale 2 miles to an inch. Vertical Scale 200 feet to an inch.

a. Totternhoe Stone. *b.* Chalk Marl.

(From Memoir "On the Geology of Cambridge," Fig. 9. p. 45.)

A boring made for the Ely Waterworks at Isleham proved the Chalk Marl to be over 70 feet deep.

In Suffolk the greater part of its outcrop or "basset surface" is concealed by alluvium and blown sand.

The Totternhoe Stone.

The outcrop of this stone enters Cambridgeshire a little east of Ashwell, and its base is seen in a clunch-pit east of Shepreth, the basement bed enclosing a number of hard green-coated nodules, which consist of marly chalk indurated by the infiltration of a certain amount of phosphate of lime.

The top of the Totternhoe Stone is exposed at the bottom of the large quarries at Cherry Hinton, and some depth of it was formerly worked for building-stone, but only 4 or 5 feet are now visible. There is no definite upper limit to the stone, but a gradual passage from rough-feeling greyish-brown stone into compact grey chalk.

The best sections of the Totternhoe Stone as a whole are to be found in the pits at Burwell, about half-way between Cambridge and Mildenhall. Here it has long been worked, and is still occasionally quarried for building-material and for mouldings in the interior of churches. The upper beds are exposed in the quarry near the church, and the section seen here in 1878 was:—

		ft.
	Soil and chalk rubble - - - - - - - - -	4
	Thin-bedded greyish-white chalk - - - - - - -	10
Totternhoe Stone.	Hard brownish-grey stone projecting in the weathered face of the pit - - - - -	3
	Softer grey stone in thick beds - - - seen for	10
		27

The uppermost bed is called the "bond" or "bond-stone" by the workmen, and makes the best building-stone. The lower beds are now generally burnt for lime; they are said to be more than 15 feet thick. Fossils are abundant, and *Am.* [*Acanthoceras*] *rotomagensis* is especially common in the "bond."

In the Victoria Quarry, to the north, the lower part of the stone is exposed, with the basal nodule-bed resting on Chalk Marl and dipping at about 3° to the westward. The following section was taken along the north face of the pit in 1878:—

	ft.
Rather hard grey Totternhoe Stone, with a nodule bed at the base, varying in thickness from 6 to 12 inches, - - about	13
Tough marly and blocky chalk-marl - - - - -	15

The nodules are calcareo-phosphatic, brownish inside, but generally green outside; they are of all sizes, from that of a pea to a medium-sized potato, irregularly oval or kidney shaped, and often bear the attached valves of small oysters and *Plicatulæ*. This nodule-bed is called "brassil" by the workmen, and is carted away for road metal, the rest of the stone as well as the Chalk Marl being burnt for lime. Analysis shows that the Totternhoe Stone here contains about 86 per cent. of carbonate of lime.

The same nodule-bed, with a few feet of the overlying stone, was once exposed at the south-western corner of the large quarries at Reach.

The Totternhoe Stone is also quarried at Isleham, 6 miles north-east of Burwell, the upper beds being seen in the quarry south of the church; here the massive blocky stone is overlain by 2 or 3 feet of hard rough grey chalk, in several irregular beds, the material being a mottled mixture of dark and lighter grey chalk. Above is firm greyish-white chalk, and there is nothing like the "bond" course of Burwell.

Chalk above the Totternhoe Stone.

As the Belemnite marls are frequently exposed in pits which also show more or less of the underlying chalk, it will be convenient to take them together, instead of separately. The first good section in Cambridgeshire is in a quarry about half a mile south of Litlington, and the chalk is so worked that the two faces of the pit form two sides of a triangle, the apex of which points N.N.E.

On the easterly side the section is:—

		ft.
Melbourn Rock	- - - - - -	10½
Belemnite Beds.	Grey marly chalk, passing down into laminated marl	2
	Hard grey and white "marbled rock," containing *Actinocamax plenus* and other fossils - - -	1
	Greyish marly chalk, passing into that below - -	2
Rather hard white chalk (see p. 190) - - - - -		6
Gritty chalk with green-coated nodules - -		1
Whitish chalk below.		

The "marbled rock" or chalk conglomerate thins out toward the apex of the triangle, and the upper marl thickens somewhat, so that along the northern face the zone consists entirely of grey marly chalk and shaly marl, and is nearly 5 feet thick.

Another good exposure is in a quarry south of Melbourn, where the dip is 5° to the south-by-east, and the beds seen are:—

		ft.
Melbourn Rock and chalk above - - - - - - - -		17½
Belemnite Beds.	Buff laminated marl - - - - - - - -	1
	Grey marly chalk - - - - - - - -	2
	Hard compact white chalk - - - - - -	2
	Grey marly chalk - - - - - - - - -	1½
White chalk, rising to the north-west, and seen for about -		26
		50

The Belemnite Beds are here unusually thick (6½ feet), and at the northern end of the pit the compact white chalk passes into the brecciated nodular condition above described. In another pit only a quarter of a mile from the above this band has its normal thickness (little more than 3 feet) and its usual composition.

These beds are seen again in a pit on Maggots Mount, near Harston, where they have a thickness of 5 feet or more.

A quarry on Steeple Hill, north-east of Shelford, gives a good section of the upper part of the Lower Chalk. The beds seen in the upper level are:—

		ft.
Melbourn Rock	- - - - - - - - - -	9
Belemnite Beds.	Grey laminated marly chalk - - - - - - -	1
	Hard compact and smooth white chalk, with *Rhynchonella* and *Ostrea vesicularis* - - - - -	1½
	Soft laminated marly chalk - - - - -	1
Blocky white chalk	- - - - seen for	5

In the lower level 25 to 30 feet of creamy white blocky chalk is seen, containing *Am.* [*Acanth.*] *rotomagensis, Holaster subglobosus, Hol. trecensis, Pecten Beaveri,* and other fossils.

The most complete exposure of the zone of *Holaster subglobosus* is in the large quarry at Cherry Hinton, near Cambridge. The highest level of this shows the basal marl of the *Act. plenus* band and about 30 feet of tough blocky chalk, of a creamy white tint when damp but drying nearly white. In the middle stage of the quarry about 25 feet of rather hard white and yellowish-white chalk is seen, in which *Holaster subglobosus* is very common. The lowest level shows about 15 feet of greyish-white chalk overlying the Totternhoe Stone.

The total thickness appears to be about 70 feet, and of this the upper 50 feet consist of white or nearly white chalk, which is more than usual; lenticular bedding or jointing is developed in a very marked manner throughout the whole zone.

Some 10 or 12 feet of the grey chalk overlying the Totternhoe Stone is exposed in the more southern quarries at Burwell, but the whiter chalk is not reached.

There is a remarkable section in a quarry near West Row, west of Mildenhall, in Suffolk, for the beds exposed differ from any elsewhere seen, and contain a band of red chalk like those of Lincolnshire.

The complete section visible here in 1886 was as follows:—

	ft.
Chalky soil - - - - - - - - - - - -	1
Rough yellowish chalk, weathered - - - - -	4
Red marly chalk, brick-red at top, lighter red below -	4
Greyish-white chalk, marly and platy, containing lenticular lumps of hard chalk - - - - - - - - -	1½
Hard grey rocky and nodular chalk - -	2
Soft grey marly chalk - - - - - - - - -	2
Very hard grey nodular chalk (*Am.* [*Haploceras*] *Austeni*, *Actinocamax plenus*, and *Terebratula semiglobosa*) - -	1
Thin-bedded whitish chalk - - - - - -	2½
Hard greyish chalk - - - - - - -	2
Softer thin-bedded chalk (*Holaster subglobosus*)	6
Hard lumpy yellowish rocky layer - -	½
Softer chalk below, according to the workmen.	
	26½

On the eastern side of the quarry, near the entrance, the dip is westward, but the beds soon become horizontal. Owing to the flatness of the country and the paucity of exposures it is impossible to be sure of the exact horizon of these beds, but it is certain that they lie somewhere between the Totternhoe Stone and the

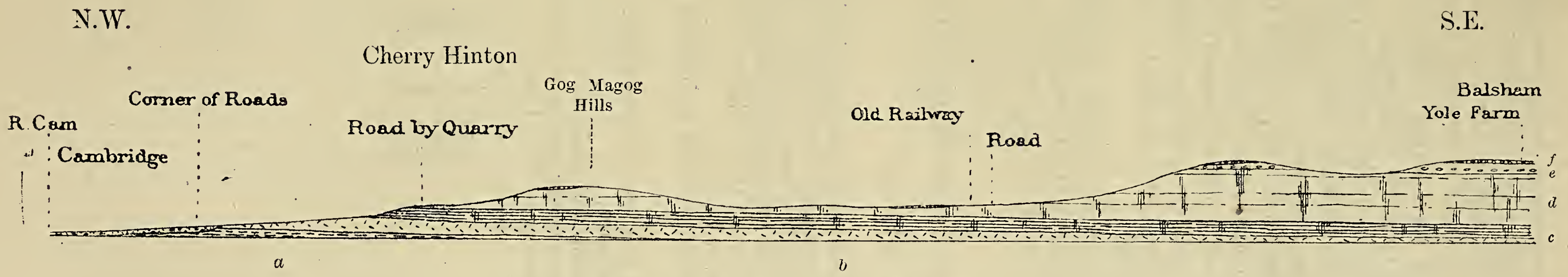

Fig 48.—Section from Cambridge to Balsham.

Horizontal Scale $\frac{3}{4}$ of an inch to a mile. Vertical Scale 800 feet to an inch.

f. Boulder Clay.
e. Upper Chalk.
d. Middle Chalk.
Lower Chalk. { *c.* Zone of *Hol. subglobosus.*
b. Zone of *Ammonites varians.*
a. Gault.

Belemnite Marls. The occurrence of *Act. plenus* with *Am.* [*Hapl.*] *Austeni* at an horizon which is apparently nearer the base than the top of this zone is remarkable and, so far as at present known, is without parallel. The bed in which they occur is a very hard grey chalk, and as it is burnt for lime, along with all the other beds below the red band, it must be fairly calcareous.

The red chalk is rather soft and marly, breaking into small angular blocks, the edges of which are pinkish white. All the joint-planes which cross this bed are also bordered by whitish bands about a third of an inch thick. These facts seem to show that the bed was originally of a uniform red colour, and that the water percolating from the surface has effected a certain amount of decoloration. Where it rises toward the surface, near the entrance of the pit, the upper part weathers yellow, and finally the whole breaks up into a rubble of yellowish chalk.

North of West Row the country slopes gradually toward the Fenland, and the surface is obscured by blown sand.

No exposure of the Belemnite Marls has yet been found in Suffolk (north of the Lark).

LIST OF FOSSILS FROM THE LOWER CHALK OF CAMBRIDGE AND SUFFOLK.

The following list of fossils is based on those given in the Survey Memoir on the Geology of the Neighbourhood of Cambridge (1881), and that on Parts of Cambridgeshire and Suffolk (Sheet 51, N.E., 1891). Most of the fossils herein recorded are in the Woodwardian Museum at Cambridge, but collections were also made from the localities mentioned by Mr. H. A. Allen for the Geological Survey in 1878.

In this list the following letters are used to indicate the localities and districts mentioned :—

a=Localities to the south and west of Cambridge.
b=Cherry Hinton and Fulbourn.
c=Swaffham, Reach, Burwell, and Isleham.
s=Localities in Suffolk, principally in the fourth column, where it signifies the large quarry at West Row.

—	Cambridge Greensand.	Chalk Marl.	Totternhoe Stone.	Chalk above Totternhoe Stone.	Belemnite Marls.
Reptilia.					
Acanthopholis eucercus, *Seeley*	x	—	—	—	—
,, stereocercus, *Seeley*	x	—	—	—	—
Anoplosaurus curtonotus, *Seeley*	x	—	—	—	—
,, major, *Seeley*	x	—	—	—	—
Cimoliosaurus Bernardi, *Owen*	x	—	—	—	—
,, planus, *Owen*	x	—	—	—	—
Emys sp.	x	—	—	—	—
Ichthyosaurus campylodon, *Carter*	x	—	—	b	—
Lytoloma cantabrigiensis, *Lyd.*	x	—	—	—	—
,, sp.	x	—	—	—	—
Macrurosaurus semnus, *Seeley*	x	—	—	—	—
Ornithocheirus Carteri, *Seeley*	x	—	—	—	—
,, Fittoni, *Seeley*	—	—	—	—	—
,, sp.	x	—	—	b	—
Polyptychodon interruptus, *Owen*	x	—	—	b	—
Trachodon cantabrigiensis, *Lyd.*	x	—	—	—	—
Saurospondylus dissimilis, *Seeley*	—	—	—	b	—

LIST OF FOSSILS FROM THE LOWER CHALK OF CAMBRIDGE AND SUFFOLK—*contd.*

——	Cambridge Greensand.	Chalk Marl.	Totternhoe Stone.	Chalk above Totternhoe Stone.	Belemnite Marls.
Pisces.					
Beryx sp. (opercular bones)	—	—	b	a b	—
Cimolichthys striatus, *Ag.*	—	—	c	—	a
Corax falcatus, *Ag.*	—	—	c	—	—
Dercetis elongatus, *Davies*	—	—	c	—	—
Edaphodon Sedgwickii, *Ag.*	x	—	—	—	—
Enchodus halocyon, *Ag.*	x	—	—	—	—
Lamna appendiculata, *Ag.*	x	a c	a b c	a b	a
„ sp.	—	—	—	—	—
Notidanus microdon, *Ag.*	x	—	c	—	—
Oxyrhina Mantelli, *Ag.*	—	—	c	a b	—
Protosphyræna ferox, *Leidy*	x	—	—	—	a
Ptychodus decurrens, *Ag.*	—	—	c	a	—
Scapanorhynchus raphiodon, *Ag.*	—	—	—	a	—
Fish vertebræ and coprolites	x	—	—	a b	a b
Cephalopoda.					
Ammonites [Haploceras] Austeni, *Sharpe*	—	—	c	s	—
„ [Acanth.] cenomanensis, *d'Arch.*	—	—	c	—	—
„ [„] Mantelli, *Sow.*	—	a	c	—	—
„ [„] navicularis, *Mant.*	—	—	c	—	—
„ [„] rotomagensis, *Brongn.*	—	—	a c	a b s	—
„ [Schloenb.] varians, *Sow.*	—	a c	c	a	—
„ [„] Coupei, *Brongn.*	—	—	c	a	—
Scaphites æqualis, *Sow.*	—	—	c	a	—
Turrilites costatus, *Lam.*	—	—	c	—	—
„ scheuchzerianus, *Bosc.*	—	—	c	—	—
„ tuberculatus, *Bosc.*	—	a	c	—	—
Nautilus deslongchampsianus, *d'Orb.*	—	—	c	—	—
„ elegans, *Sow.*	—	—	c	—	—
„ reflectus, *Seeley*, MS.	—	—	c	—	—
Actinocamax lanceolatus, *Sow.*	—	—	c	—	—
„ plenus, *Blainv.*	—	—	—	s	a b
Belemnites minimus, var ultimus, *d'Orb.*	x	—	—	—	—
Gasteropoda.					
Aporrhais sp.	—	—	c	—	—
Cerithium ornatissimum, *Desh.*	—	—	c	—	—
Dentalium majus, *Gard.*	—	—	c	—	—
Fusus sp	—	—	c	—	—
Pleurotomaria brongniartiana ? *d'Orb*	—	—	c	—	—
„ (several species)	—	—	c	—	—
Scalaria fasciata, *Eth.*	—	—	c	—	—
Solarium dentatum ? *Desh.*	—	—	c	—	—
Trochus sp.	—	—	c	—	—
Turbo sp.	—	—	c	—	—
Lamellibranchiata.					
Anomia papyracea, *d'Orb.*	—	—	c	—	—
„ transversa, *Seeley*	x	—	—	—	—
Avicula dubia, *Eth.*	—	—	c	—	—
„ filata, *Eth.*	—	—	c	—	—
Aucellina gryphæoides, *Sow.*	x	—	b c	a	—
Exogyra haliotoidea, *Sow.*	x	—	c	a b	—
Inoceramus convexus, *Eth.*	—	—	c	—	—
„ latus *d'Orb.* non *Mant.*	—	a c	a c	—	—
„ mytiloides, *Sow.*	—	—	—	a	c
„ striatus, *Sow.*	—	—	c	—	—
Lima aspera, *Mant.*	—	—	c	—	—
„ echinata, *Eth.*	—	—	b c	—	—
„ globosa, *Sow.*	x	a c	a b c	a b	—
„ ornata, *Eth.* non *d'Orb.*	x	—	—	—	—
Ostrea acutirostris, *Nilss.*	—	—	c	—	—
„ curvirostris, var inflexa, *Eth.*	—	—	a c	—	—
„ cunabula, *Seeley*	x	—	—	—	—
„ frons, *Park.*	x	a	c	—	—
„ lagena, *Seeley*	x	—	—	—	—
„ normaniana, *d'Orb.*	—	—	—	b	a b c
„ vesicularis, *Lam.*	x	a c	a b c	a b c s	a b c
Pecten Beaveri, *Sow.*	—	—	c	a b	—
„ dubrisiensis, *Woods*	—	c	b c	s	
„ elongatus, *Lam.*	—	—	c	—	—
„ fissicosta, *Eth.*	—	—	a b c	—	—

LIST OF FOSSILS FROM THE LOWER CHALK OF CAMBRIDGE AND SUFFOLK—*contd.*

——	Cambridge Greensand.	Chalk Marl.	Totternhoe Stone.	Chalk above Totternhoe Stone.	Belemnite Marls.
Lamellibranchiata.—contd.					
Pecten orbicularis, *Sow.*	x	a	a b c	a b c s	—
„ (Neithea) quinquecostata, *Sow.*	—	—	c	a	—
Pholadomya decussata, *Phil.*	—	—	c	—	—
Pinna tegulata, *Eth.*	—	—	c	—	—
Plicatula inflata, *Sow.*	x	a c	a b c	a b c	—
„ minuta, *Seeley*	x	—	—	—	—
„ sigillina, *Woodw.*	x	—	—	—	—
Radiolites Mortoni, *Mant.*	x	—	—	—	—
Spondylus latus, *Sow.*	—	—	—	a b	—
„ striatus, *Sow.*	—	—	c	—	—
Teredo amphisbæna, *Goldf.*	x	—	c	b	—
Brachiopoda.					
Megathyris megatrema, *Sow.* (Argiope	x	—	—	—	—
Kingena lima, *Defr.*	x	a c	a b c	a b c	—
Rhynchonella grasiana, *d Orb.*	—	a c	a c	—	—
„ Cuvieri, *d'Orb.*	—	—	—	—	a b c
„ lineolata, *Phil.*	x	—	—	—	—
„ mantelliana, *Sow.*	x	a c	a b c	a b c s	—
„ Martini, *Mant.*	?x	a c	c	a	—
„ plicatilis, *Sow.*	—	—	—	—	a b c
Terebratula biplicata, *Sow.*	x	a c	c	a c s	a
„ semiglobosa, *Sow.*	x	a c	a b c	a b c s	a b
„ squamosa, *Mant.*	—	—	a c	c s	—
„ sulcifera, *Morris*	x	—	b c	a b s	—
Terebratulina nodulosa, *Eth.*	—	c	a b c	—	—
„ striata, *Wahl.*	x	a c	a c	a b	—
„ triangularis, *Eth.*	x	a	—	—	—
Thecidium Wetherelli, *Morris*	x	—	—	—	—
Bryozoa.					
Clinopora striatopora, *Vine*	x	—	—	—	—
Diastopora cretacea, *Vine*	x	—	—	—	—
„ Hagenowi, *Reuss*	x	—	—	—	—
Entalophora gigantopora, *Vine*	x	—	—	—	—
„ virgula, *Hag.* var. elegans, *Vine*	x	—	—	—	—
„ „ var. raripora, *d'Orb.*	x	—	—	—	—
Filisparsa ornata, *Reuss*	x	—	—	—	—
Idmonea cenomana, *d'Orb.*	x	—	—	—	—
Membranipora dumerilla, var. cantabrigensis, *Vine*	x	—	—	—	—
Microporella antiquata, *Vine*	x	—	—	—	—
Reptomulticava favus, *Seeley*	x	—	—	—	—
„ radiata, *Vine*	x	—	—	—	—
Proboscina augustata, *d'Orb.*	x	—	—	—	—
„ hunstantonensis, *Vine*	x	—	—	—	—
„ gigantopora, *Vine*	x	—	—	—	—
„ ramosa, *d'Orb.*	x	—	—	—	—
Reptomultisparsa fœcunda, *Vine*	x	—	—	—	—
„ megalopora, *Vine*	x	—	—	—	—
Siphoniotyphlus plumatus, *Lonsd.*	x	—	—	—	—
Stomatopora graciliformis, *Vine*	x	—	—	—	—
„ linearis, var. Mortoni, *Vine*	x	—	—	—	—
Spiropora Jessoni, *Vine*	x	—	—	—	—
Umbrellina paucipora, *Vine*	x	—	—	—	—
Crustacea.					
Enoploclytia brevimana, *McCoy*	—	—	c	—	—
„ Imagei, *Mant.*	—	—	c	—	—
Glyphæa cretacea, *McCoy*	—	—	c	—	—
Necrocarcinus Woodwardi, *Bell*	—	—	c	—	—
Palæga Carteri, *Woodw.*	x	—	—	—	—
Pollicipes glaber, *Sow.*	x	—	c	—	—
„ unguis, *Sow.*	x	—	—	—	—
Scalpellum maximum, *Sow.*	—	—	c	—	—
„ arcuatum, *Darw.*	x	—	—	—	—

List of Fossils from the Lower Chalk of Cambridge and Suffolk—*contd.*

—	Cambridge Greensand.	Chalk Marl.	Totternhoe Stone.	Chalk above Totternhoe Stone.	Belemnite Marls.
Echinodermata.					
Astrogonium sp.	x	—	—	—	—
Cidaris Bowerbanki, *Forb.* (spines)	x	—	—	b	—
„ Dixoni, *Cott.* (spines)	x	—	—	—	—
„ dissimilis, *Forb.* sp.	x	a	a	a b	—
„ hirudo, *Sorig.* (spines)	—	—	—	a	a ?
„ gradata, *Seeley*	x	—	—	—	—
„ Sedgwicki, *Seeley*	x	—	—	—	—
„ vesiculosa, *Goldf.*	x	—	—	—	—
Discoidea cylindrica, *Lam.*	x	—	c	—	—
„ subuculus, *Klein*	x	c	c	—	—
Echinocyphus difficilis, var. impressa, *Seeley*	x	—	—	a b s	—
Goniaster (ossicles)	—	—	—	—	—
Goniophorus lunatus, var. minutus, *Seeley*	x	—	—	—	—
Hemiaster Morrisi, *Forbes*	—	—	c	—	—
Holaster trecensis, *Leym.*	—	—	—	a s	—
„ subglobosus, *Leske*	x	—	a c	a b c s	—
Peltastes Bunburyi, *Wright*	—	—	—	?s	—
Pentacrinus Fittoni, *Austen*	x	—	c	—	—
Pseudodiadema sp.	—	—	c	—	—
Salenia Woodwardi, *Seeley*	x	—	—	—	—
Annelida.					
Serpula annulata, *Reuss*	—	a c	—	—	—
„ antiquata, *Sow.*	—	—	b c	—	—
„ rustica, *Sow.*	—	—	c	—	—
„ umbonata, *Mant.*	x	a	a b c	—	—
Actinozoa.					
Cœlosmilia sp.	—	—	—	—	—
Micrabacia coronula, *Goldf.*	x	—	c	—	—
Onchotrochus serpentinus, *Dunc.*	x	—	b	—	—
Hydrozoa.					
Parkeria sp.	x	—	—	—	—
Spongida.					
Pharetrospongia Strahani, *Sollas*	x	—	—	—	—

CHAPTER XVII.

THE LOWER CHALK IN NORFOLK.

General Description.

In the southern part of Norfolk, between the rivers Little Ouse and Wissey, the base of the Chalk lies below the Fenland, but it comes to the surface near Stoke Ferry, and continues above sea-level, though often obscured by Drift till it passes beneath the sea near Hunstanton.

The Lower Chalk undergoes great changes as it passes from the south to the north of this county, and its thickness is at the same time greatly diminished. Near Stoke Ferry the total thickness of the Lower Chalk is probably about 125 feet, but this decreases rapidly northward; at Marham it is about 90 feet, and at Hunstanton it is reduced to about 56 feet.

The Chalk Marl or Zone of Ammonites varians.—This has a bed of glauconitic chalk at its base between Stoke Ferry and Shouldham, but the glauconite grains are very small. Farther north this bed disappears, and a hard white chalky limestone rests directly on the Gault marls. In the southern part of the county, as far north as Stoke Ferry, the Chalk Marl consists of alternating soft and hard beds, and it maintains a thickness of 70 to 75 feet; but north of Stoke the soft beds seem to thin out, and the harder beds become more purely calcareous, owing to the elimination of the siliceous and argillaceous ingredients, so that in the northern part of the county the zone of *Am. varians* consists entirely of hard greyish-white chalk, and at Hunstanton is only 18½ feet thick. This must be regarded as a condensed equivalent of the Chalk Marl. The change may be compared with that which takes place in Dorset, where the marly beds similarly thin out (see p. 108).

Zone of Holaster subglobosus.—In Norfolk, *Holaster subglobosus* is again found in the beds below the Totternhoe Stone and consequently ceases to be a good index for the higher zone, while *Offaster sphæricus* has not yet been found in this county.

This zone has the usual bed of Totternhoe Stone at the base, and at Stoke Ferry the thickness of this stone is about 4 feet, but at Hunstanton it is only 2 feet. It is a tough grey gritty chalk, with a layer of irregular green or yellow-coated nodules at its base, like those in the "brassil" of Burwell. As usual, it is mainly composed of comminuted fragments of shell (60 to 70 per cent.), and glauconite is present in some quantity, but quartz grains are few and very small.

Above the Totternhoe Stone there is some thickness of hard grey chalk, irregularly bedded in the lower part, but smoother and more blocky above. This passes up rapidly into white chalk, which becomes very hard in the northern part of the county. Between Stoke Ferry and Gayton the thickness of chalk between the Totternhoe Stone and the summit of the Lower Chalk is probably not less than 50 feet, but near Hunstanton it is only 36 feet.

The Belemnite Beds at the top of this zone are represented in the southern part of the county by a layer of yellowish marly chalk enclosing lumps of hard white chalk. This extends as far north as Hillington, but then becomes a mere parting, and is not distinguishable near Hunstanton, where the hard Lower Chalk and the Melbourn Rock make a continuous face in the quarries.

STRATIGRAPHICAL DETAILS.

Zone of Ammonites varians.

Several small quarries expose the higher part of this zone between Hockwold Grange and Feltwell St. Nicholas, but a complete section of the zone was obtained by a boring made for Mr. W. Hill and the author in the quarries at Stoke Ferry.* The results of this, combined with measurements of the beds seen in quarry, are shown in the diagram, Fig. 49.

The intercalation of hard beds with the softer marly beds is here very conspicuous; most of the harder courses are shelly, but that which commences 11 feet above the basement bed is less shelly, and has a special structural aspect which is different from that of ordinary Chalk Marl (see p. 282).

The highest part of the zone also consists of blocky, compact, dull white chalk, about 24 feet thick, which is hard enough to resound under the hammer. This likewise is largely composed of fine calcareous material, the shell fragments and glauconite grains being all very small. This hard chalk contains *Holaster subglobosus,* which is absent from or very rare in the Chalk Marl of the more midland counties.

The basement bed, still glauconitic with many small green-coated phosphatic nodules, is exposed in a small pit by the roadside south of Shouldham Church. It is here overlain by rather hard yellowish chalk in lumpy irregular beds, like that which was found in the Stoke boring from 11 to 21 feet above the basement bed; hence it would seem that the intervening 11 feet of soft marl has either thinned out or has changed laterally into a harder and more calcareous chalk.

There is no other good exposure of Chalk Marl till we come to Grimston, and here, at the Sow's Head spring, the base of the Chalk is again seen. It consists of a very hard solid limestone, weather-

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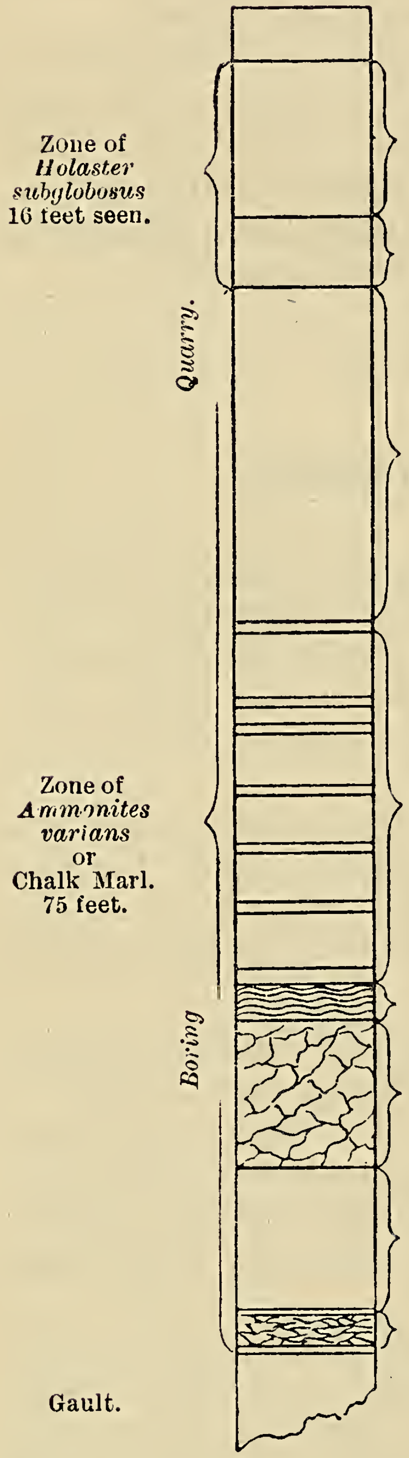
* See Quart. Journ. Geol. Soc., Vol. xliii., p. 556 (1887).



Quarry.		ft
Soil and gravel	about	4
Hard whitish chalk passing down into greyish bedded chalk - - - - - - - - - -		12
Tough grey sandy-looking chalk, becoming harder below and containing many yellowish phosphatic nodules at the base (Totternhoe Stone) - - -		4
Band of mottled grey and white chalk - - -		1
Hard whitish chalk, without definite bedding, weathering to a rough lumpy surface with a yellowish tinge -		22
Boring.		
Rubble of broken chalk - - - - - - - -		2
Hard greyish shelly chalk, with interbedded softer layers - - - - - - - - -		14
The like with buff stains or blotches, hardest in the lower three feet - - - - - - - - -		12
Softer chalk grey and marly, mottled with paler bluish-grey material - - - - - - - -		2
Hard light buff chalk, shelly, with black streaks (? oxide of manganese), passing down into less hard and less shelly dull grey chalk - - - - -		10
Soft whitish marl, with a harder lump here and there, but mostly cutting like cheese - - - - -		11
Tough grey sandy marl with yellowish streaks, containing glauconite grains and small phosphate-nodules - - - - - - - - - -		2½
Stiff dark blue clay - - - - -	proved to	1½
		97

FIG. 49.—The succession shown in the quarry and boring at Stoke Ferry. Scale, 20 feet to an inch.

(From Memoir "On the Geology of S.W. Norfolk and Northern Cambridgeshire" (1893), p. 31.)

ing to a creamy yellow tint. Of this limestone 3 or 4 feet are seen, resting directly on and passing down into the pale grey marls of the Upper Gault without anything like the usual glauconitic basement bed. In minute structure it is a purer and more compact form of the rock which overlies the basement bed at Shouldham. The only fossils seen were small *Belemnites* and a small species of *Rhynchonella*.

A small pit about half a mile N.N.E. of Roydon Church discloses an important section, because it shows the whole of this hard whitish rock and some of the overlying chalk, the beds seen being as follow :

	ft.
Hard greyish gritty chalk, weathering into flaggy pieces, and containing at the base a number of green-coated nodules -	6
Very hard creamy-white chalk, piped at the top with material from above - - - - - - - -	5½

It has been ascertained by boring that this lower bed rests directly on the marly clay of the Gault (see Vol. i., p. 300). The importance of this exposure is that the gritty chalk is undoubtedly correlative with the " Inoceramus Bed " of Hunstanton. We think also that it is likewise the condensed equivalent of the central part of the Chalk Marl at Stoke Ferry, *i.e.*, the greyish shelly chalk traversed in the boring mentioned on p. 208, just as the whitish chalky limestone below is the condensed equivalent of the softer Chalk Marl proved in the lower part of the Stoke Ferry boring.

The great condensation which has taken place in the Chalk Marl as a whole, by the elimination of the marly or rather the argillaceous ingredient, is shown by the section obtained in the large chalk-pit at Dersingham. Here below the Totternhoe Stone about 8 feet of hard creamy-white chalk is exposed, becoming rather greyer below; while a boring made through the floor of the pit in 1886 disclosed the following beds* :—

	ft.
Hard greyish chalk, becoming greyer and more gritty below, with yellowish green-coated nodules near the base - -	8
Very hard compact white chalk - - - - - -	1½
Gault marls below.	

Here therefore the total thickness of the chalk between the Gault and the Totternhoe Stone is only 17½ feet, as compared with 75 feet at Stoke Ferry.

At Hunstanton it is only a foot thicker, and the section is practically the same. See Fig. 50, which is reproduced from the paper by Mr. W. Hill and the author, already referred to.

The hard white chalk which overlies the " Red Chalk " of Hunstanton has long been known as " the sponge bed," on account of the curious cylindrical bodies which it contains, and which resemble the stems of *Siphonia*, but do not exhibit any sponge structure.

The succeeding grey shelly chalk is generally called the "*Inoceramus* bed," from the number of broken *Inocerami* which it contains.

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* See Quart. Journ. Geol. Soc., Vol. xliii., p. 560 (1887).

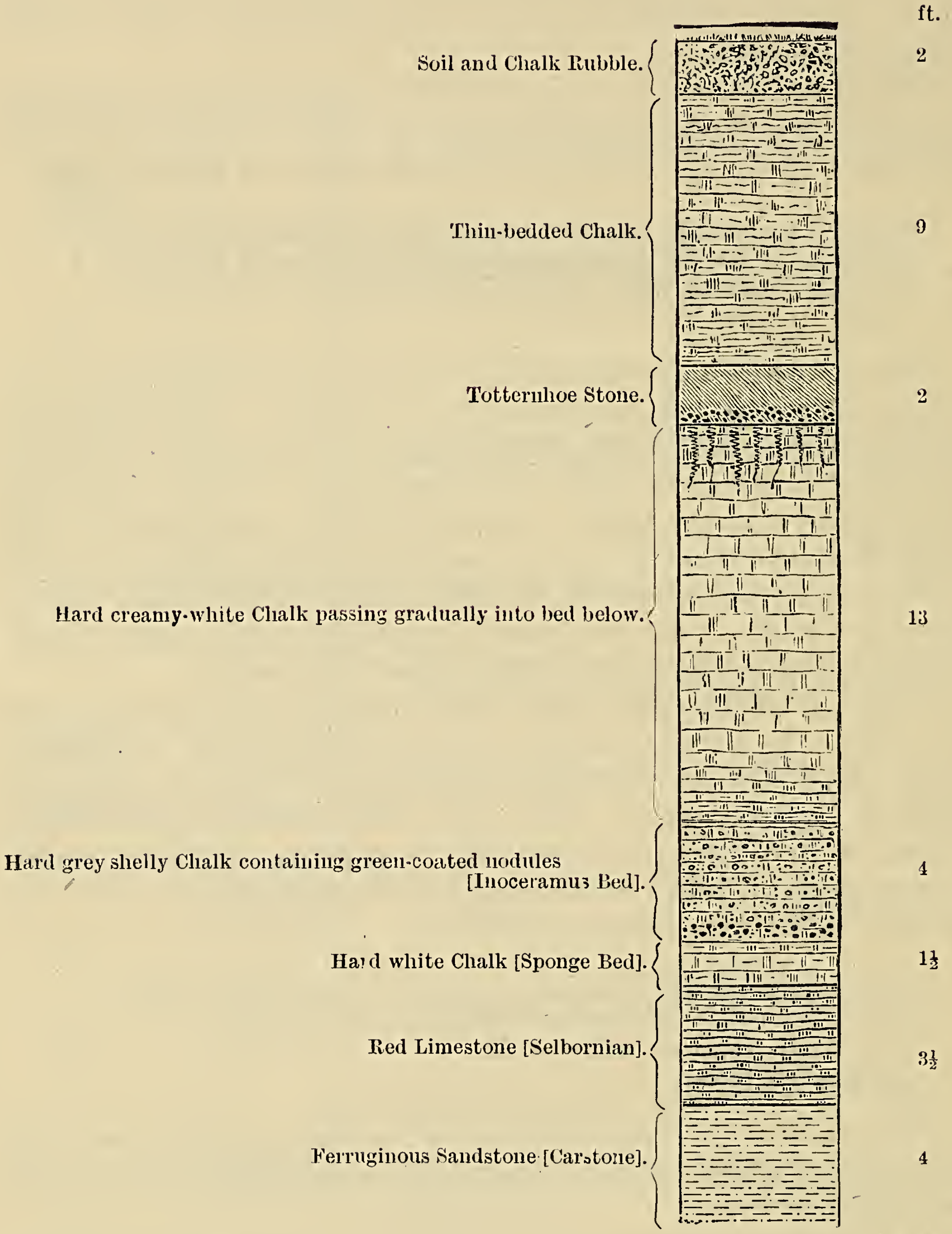
ft.
Soil and Chalk Rubble.
2
Thin-bedded Chalk.
9
Totternhoe Stone.
2
Hard creamy-white Chalk passing gradually into bed below.
13
Hard grey shelly Chalk containing green-coated nodules [Inoceramus Bed].
4
Hard white Chalk [Sponge Bed].
1½
Red Limestone [Selbornian].
3½
Ferruginous Sandstone [Carstone].
4

FIG. 50.—Vertical Succession of the beds in Hunstanton Cliff. From Quart. Journ. Geol. Soc., vol. xliii., p. 562.

Scale 8 feet to an inch.

These are chiefly *Inoceramus latus*, d'Orb, the common Chalk Marl species. *Holaster subglobosus* is also very abundant. The rough gritty feel of the rock is due to the quantity of comminuted shell, about 60 per cent. of its mass consisting of such fragments.

Zone of Holaster subglobosus.

Totternhoe Stone.—The outcrop of this bed has not yet been found in the extreme south of the county between the courses of the Little Ouse and the Wissey, but it is exposed in the large quarry at Stoke Ferry, the section of which is shown in Fig. 49, p. 208.

The Totternhoe Stone is about 4 feet thick, and has the usual aspect of a tough grey sandy-looking stone, coming away in large blocks. There is a layer of cream-coloured calcareo-phosphatic nodules at its base, some of them being greenish outside, but there is no marked plane of division below these as at Burwell. The grey shelly or gritty material of the stone is piped into the light-coloured chalk below for about 12 inches, thus forming a band of mottled chalk, which comes away with the overlying stone. *Rhynchonella mantelliana* is, as usual, a common fossil. Upward the stone passes rapidly into greyish-white bedded chalk.

No exposure of Totternhoe Stone has yet been found near Wereham or Marham, though it must run through the village of Marham. It is, however, clearly seen in the chalk-pit at Dersingham, where the section is :—

	ft.
Thin-bedded rather hard greyish-white chalk - - - - -	16
Hard, tough, and massive grey chalk, with a layer of green-coated nodules at bottom - - - - - - - -	$2\frac{1}{2}$
Hard creamy-white chalk - - - - - seen for	8

A similar succession is exposed in quarries at Snettisham and Heacham, and in the cliffs at Hunstanton (see Fig. 50). At Heacham and Hunstanton its thickness is only 2 feet, but it forms a conspicuous feature in the cliff-face.

Exposures of the Higher Beds.—The only noteworthy exposure between Hockwold and Stoke Ferry is at Feltwell St. Mary, where in a dry pond by the roadside, a quarter of a mile north-east of the church, Mr. W. Hill and the writer found a small exposure of pink chalk, weathering yellow, like that of West Row in Suffolk, and resting on a course of hard nodular rock, with soft whitish chalk below; the succession thus agreeing most remarkably with that ten miles away.

The upper beds of the Lower Chalk are exposed in the quarry at Whittington, where the following succession was seen in 1886 :—

		ft.
	Melbourn Rock - - - - - - - -	7
Lower Chalk.	Buff-coloured marl, enclosing lumps of hard whitish chalk - - - - - - - - - - -	$1\frac{1}{2}$
	Very hard white lumpy chalk - - - - about	3
	Hard blocky white chalk, becoming greyish-white below	12

The hard white chalk evidently represents the upper and whiter portion of the *H. subglobosus* zone at Cherry Hinton, but here the top part is rough, lumpy, and very hard. The overlying marl appears to be the attenuated representative of the Belemnite Beds; it is much thinner and its surfaces are less clearly defined than in Cambridgeshire, but it contains that variety of *Rhynchonella plicatilis* which is so commonly found at this horizon.

A quarry about half a mile south of Barton Bendish exhibits a similar section as above, and there is a good exposure of the same beds at Marham limekiln, where the following section was seen by us in 1886 (Op. cit. p. 567):—

	ft.
Thin soil and weathered Melbourn Rock - -	5
Band of yellow marly chalk, with a layer of grey marl at the base - - - - - - - - - - -	1½
Hard white chalk, weathering rough and projecting over the face below - - - - - - - - -	9
Blocky greyish chalk - - - - - - - - -	10
About	25

At the north corner there is a marked layer of nodular rock at the base of the hard white chalk, but it is not continuous. A similar section is shown in the pit south-east of the church.

A little north of the first quarry are two cottages, and we were informed by the Rev. H. J. Sharpe, Vicar of Marham, that a well was sunk here to a depth of 85 feet, clay being reached at that depth and bored into for 30 feet. As the cottages are very little below the outcrop of the Melbourn Rock we may estimate the thickness of the Lower Chalk here at about 90 feet, which is about 40 feet less than its probable thickness near Stoke Ferry.

A quarry at Gayton, N.N.W. of the church, is worked in two levels and exposes about 46 feet of the zone of *Holaster subglobosus*, the section being as follows:—

	ft.
Upper Level.	
Soil and rubble - - - - - - - - - - -	1
Dull white chalk, rather tough, weathering into platy pieces	20
Lower Level.	
Firm white chalk in thicker beds - - - - - - -	12
Hard chalk, parting along greenish marly seams - - -	2½
Greyish marly chalk in massive beds - - - - - -	12

Mr. Whitaker says of this pit that "its great interest lies in the fact that small boulders of granitic, gneissose, and trap rocks are found in the chalk. . . . There were in 1882 a few large pebbles, up to 9 inches in length, lying in the pit. These are said to be found in the chalk at some depth, and there is certainly no other apparent source for them, the Chalk being quite bare [of Drift] . . . I took away one, and on a later visit several others, which are now in the Jermyn Street Museum."*

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* The Geology of South-Western Norfolk, Explanation of Sheet 65, Mem. Geol. Survey, p. 35, 1893.

Mr. Whitaker also observed that the large disused quarry to the west, on the other side of the lane, is in hard grey chalk. The lowest chalk seen in it was hard and gritty, and when a sample was sliced and examined by Mr. Hill under the microscope it proved to contain glauconite grains. Probably, therefore, it is close to, if not actually, the top of the Totternhoe Stone.

The highest beds are again seen at Hillington, the lower part of the pit showing the following section :—

	ft.
Whitish thin-bedded chalk (? Melbourn Rock) - - -	4½
Thin band of yellowish marl (? Bel. marl) - - - -	
Hard massive whitish chalk - - - - - - - -	4
Bedded chalk, dull white, with greyer beds at intervals, *Holaster subglobosus* and *Discoidea cylindrica* - - -	10

The lower beds clearly belong to the Lower Chalk, and it seems probable that the thin band of marl represents the zone of *Act. plenus* here on the point of thinning out.

The lower part of the *H. subglobosus* zone is seen at Dersingham, and the central part in a pit at Ingoldsthorpe, but the whole of it is exposed in the two quarries at Heacham, where the following beds are shown :—

Upper Pit.	ft.
Weathered chalk and Melbourn Rock - - - - -	9
Hard thin-bedded whitish chalk, with a marly band about a foot from the top - - - - - - -	6
Lower Pit.	
Thin-bedded whitish chalk, becoming greyer and thicker bedded towards the base - - - - - - - -	30
Totternhoe Stone—darker grey chalk, with green-coated nodules at the base - - - - - - - -	2
Hard cream-white chalk - - - - - seen for	12

Here, therefore, there is only 36 feet of chalk between the Totternhoe Stone and the Melbourn Rock, and there is nothing to represent the marl beds of the *Act. plenus* zone.

At Hunstanton only 9 or 10 feet of thin-bedded greyish chalk are seen above the Totternhoe Stone (see Fig. 50), the higher part of this zone not coming into the cliff.

LIST OF FOSSILS FROM THE LOWER CHALK OF NORFOLK.

This list is compiled from the joint paper by Mr. Hill and myself, published in the Quart. Journ. Geol. Soc., Vol. xliii. p. 544 (1887) and from that in the Survey Memoir on the Geology of the Borders of the Wash (1899). The letter s signifies that the species was found at Stoke Ferry or at places to the southward; n=places between Stoke Ferry and Hunstanton; and h=Hunstanton cliff.

LIST OF FOSSILS FROM THE LOWER CHALK OF NORFOLK.

——	Chalk Marl.	Tottern-hoe Stone.	Chalk above T. St.	Belem. Marl.
Pisces.				
Beryx		n	n	
Cimolichthys lewesiensis, *Leidy*		n		
Edaphodon sp.		n		
Enchodus sp		n	n	
Lamna appendiculata, *Ag.*	h			
,, sp.		n		
Ptychodus decurrens, *Ag.*			n	
Cephalopoda.				
Ammonites [Haploceras] Austeni, *Sharpe*	h			
,, [Acanth.] cenomanensis, *d'Arch*			r	
,, [Hapl.] lewesiensis ? *Mant.*			s n	
,, [Desm.] planulatus ? *Sow.*			n	
,, [Acanth.] rotomagensis, *Brongn.*	h	n		
,, Schloenb. varians, *Sow.*	s			
,, [,,] Coupei, *Brongn.*		n		
Turrilites costatus, *Lam.*		n		
,, tuberculatus, *Bosc.*		n		
,, sp.	n			
Actinocamax plenus, *Blainv.*			h	
Belemnites minimus, *Lister*	n h	n		
,, ,, var. ultimus, *d'Orb.*	h			
Nautilus sp.				
Gasteropoda.				
Pleurotomaria	h	h		
Trochus cirrus ? *Woodw.*		n		
Lamellibranchiata.				
Aucellina gryphæoides, *Sow.*	n h			
Avicula filata, *Eth.*		n		
,, roxelana ? *d'Orb.*			h	
,, new sp.		n		
Exogyra haliotoidea, *Sow.*		n		
Inoceramus latus, *d'Orb.* non *Mant.*	s n h	s n		
,, mytiloides, *Mant.*			n	
,, striatus, *Sow.*	h			
Lima cenomanensis, *d'Orb.*	h		n h	
,, echinata, *Eth.*	n h			
,, elongata, *Sow.*			h	
,, globosa, *Sow.*	n h	s n		
,, ovata ? *Nilss.*	h			
Ostrea frons, *Park.*	h			
Lesueuri, *d'Orb.*			h	
,, pectinata, *Lam.*	h			
,, vesicularis, *Lam.*	h	n h	n	
,, sp.		n		
Pecten Beaveri, *Sow.*	h	n h		
,, dubrisiensis, *Woods.*			s	
,, elongatus, *Lam.*	h			
,, orbicularis, *Sow.*	h	s n h	n	
Plicatula inflata, *Sow.*	s n h	s n h	n h	
Spondylus lineatus, *Goldf.*	h			
,, striatus, *Sow.*	h			

List of Fossils from the Lower Chalk of Norfolk.—*contd.*

——	Chalk Marl.	Totternhoe Stone.	Chalk above T. St.	Belem. Marl.
Brachiopoda.				
Kingena lima, *Defr.*	h	s h	n h	
Magas Geinitzi, *Schloenb.*			h	
Rhynchonella Cuvieri ? *d'Orb.*	n h	n	n h	
,, grasiana, *d'Orb.*	n h		n	
,, lineolata ? *Phil.*	h		n	
,, mantelliana, *Sow.*	s n h	s n h		s
,, Martini, *Mant.*	n	n	n h	
,, plicatilis, *Sow.*				
Terebratula biplicata, *Sow.*	s n h	s n h	n	s
,, obesa, *Sow.*		n		
,, semiglobosa, *Sow.*	s n h	s n h	s n h	
,, sulcifera, *Morris*	h			
,, squamosa, *Mant.*			s h	
Terebratulina nodulosa, *Eth.*	h	n h	h	
,, striata, *Wahl.*	h			
,, triangularis, *Eth.*	n h	h	n h	
Crustacea.				
Pollicipes glaber, *Roemer*		s		
,, unguis, *Sow.*	h	n		
Annelida.			h	
Ditrupa difformis, *Lam.*				
Serpula annulata, *Reuss*	h	n		
,, antiquata, *Sow.*	s			
,, subtorquata, *Münst.*			n h	
,, umbonata, *Sow.*	n h	s	h	
Echinodermata.				
Cidaris Bowerbanki, *Forbes*			n	
,, dissimilis, *Forbes*	h		n	
,, uniformis, *Sorig.*			h	
,, vesiculosa, *Goldf.*	h	h		
,, sp. (spines)		n	n	
Discoidea cylindrica, *Lam.*	h	n	s n h	
Epiaster crassissimus, *d'Orb.*	h			
Holaster lævis, *de Luc*	h			
,, subglobosus, *Leske*	s n h	s n h	s n	
,, trecensis, *Leym.*			s	
Pseudodiadema ornatum, *Goldf.*	h			
,, variolare, *Brongn.*	h			
Salenia Austeni, *Forbes*			h	
Actinozoa.				
Onchotrochus serpentinus, *Dunc.*	h		n h	
Spongida.				
Leptophragma Murchisoni, *Goldf.*	h			
Plocoscyphia labrosa, *Mant.*	n h			
Strephinia convoluta, *Hinde*	h			
Ventriculites sp.	n			

CHAPTER XVIII.

THE LOWER CHALK IN LINCOLNSHIRE.

General Description.

The Lower Chalk of Lincolnshire presents a succession of beds which is similar to that of the northern part of Norfolk, but as a whole it is thicker, being from 75 to 80 feet thick as compared with the 55 feet of North Norfolk, and this thickening is principally in the lower part or zone of *Am. varians*.

The Cretaceous escarpment is the dominant feature in East Lincolnshire, and the Wolds form a tableland trenched by the valleys of numerous streams, which all drain eastward into the North Sea. No great thickness of Middle or Upper Chalk is present, so that most of these valleys cut into the Lower Chalk, and some of them expose the "Red Chalk" (Selbornian) and underlying strata. In consequence of this structure, there are numerous exposures of the Lower Chalk, not only along the main escarpment, but in the valleys which intersect the Wolds.

The Chalk emerges from beneath the Drift-covered country between Gunby and Welton, not far from the Burgh Station on the East Lincolnshire Railway, and strikes thence to the north-west through Sheets 84, 83, and 86 of the Geological Survey Map.

Fig. 51 is a tabular view of the vertical succession of the beds forming the Lower Chalk, with the underlying Red Chalk (Selbornian), as developed in the country round South Thoresby, Louth, and Withcall. It is only in this area that the portions indicated are coloured pink; the succession is the same both to the south and to the north of this district, but the whole of the beds above the "grey bed" are greyish or yellowish-white in other parts of the county.

The Zone of Ammonites varians is about 34 feet thick at the south end of the Lincolnshire Wolds, and rather more near Louth. It has two well-marked beds at the bottom which clearly correspond with those described under the names of "Sponge Bed" and "*Inoceramus* Bed" at Hunstanton. Both, however, are thicker in Lincolnshire.

The "Sponge Bed" is a hard compact limestone, either white or yellowish-white, and sometimes partly pink in colour. It is a very pure limestone, and is entirely devoid of quartz or glauconite grains. Its thickness varies from 18 inches to 3 or 4 feet, and sometimes it is difficult to separate it from the Red Rock below.

The *Inoceramus* Beds are generally from 4 to 6 feet thick, and lie in two or three courses, with marly partings. They consist of rough grey gritty chalk, often somewhat nodular, and always full of *Inoceramus* shells.

The remainder of the zone consists of rather rough greyish chalk in thin irregular beds, with partings of shaly marl in the upper part. *Am.* (*Schloenbachia*) *varians* is not very common, while *Holaster subglobosus* and *Discoidea cylindrica* occur in most exposures.

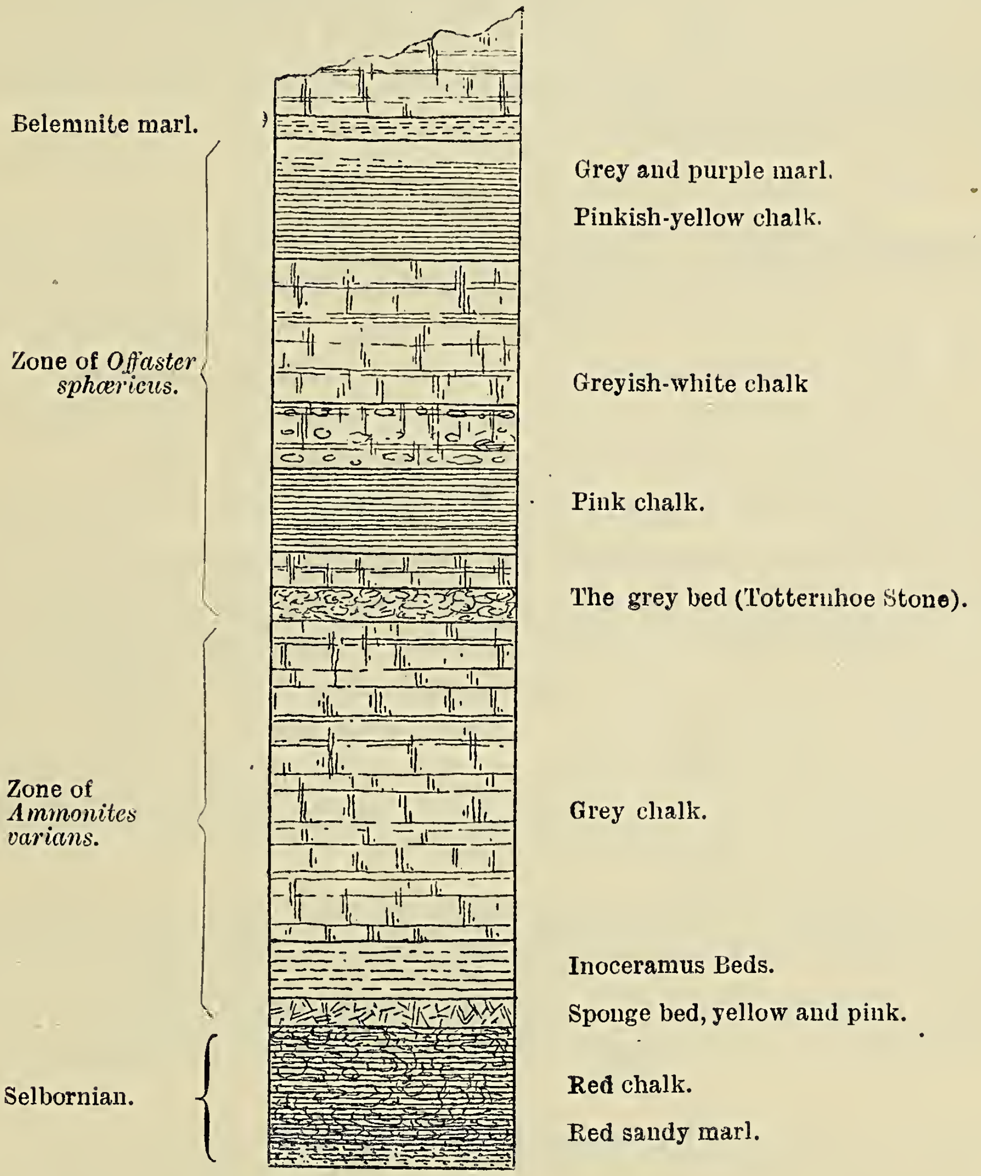

FIG. 51.—VERTICAL SECTION OF LOWER CHALK IN LINCOLNSHIRE.

The Zone of Offaster sphæricus.—In consequence of the extended range of *Holaster subglobosus* in Lincolnshire and Yorkshire, *Offaster sphæricus* has been adopted as the index of the higher zone. At its base there is a small representative of the Totternhoe Stone in the form of one or two beds of hard rough grey chalk. Sometimes it occurs as a massive bed of hard nodular chalk breaking into large blocks, but more often there are two beds, the lower one rough and nodular, the upper one compact, massive, and blocky. This grey chalk is generally from 3 to 4 feet thick, and contains many fossils. It was called the "grey bed" by Mr. W. Hill, who first identified it with the Totternhoe Stone in 1887, after he and I had traced that stone through Norfolk in the previous year.* In minute structure it is also comparable with typical Totternhoe Stone, for it consists chiefly of minute fragments of shell, with many Foraminifera and an abundance of glauconite grains.

Immediately above the Totternhoe Stone there is always a course of hard nodular greyish-white chalk, in which large Ammonites (*Hapl. lewesiensis* and *Hapl. Austeni*) frequently occur. The next 6 or 7 feet are marly, and in the Louth district they are of a pink or light red colour. Above this band are thick beds of hard whitish chalk, part of which is, however, coloured pink or yellowish-pink in the Louth district.

The total thickness of this part of the zone is from 38 to 40 feet.

Belemnite Marl.—After the disappearance of these marls in Norfolk it is somewhat surprising to find them well developed in Lincolnshire. There is, however, no doubt about their occurrence, for not only do they occur in the same relative position as those of Cambridge and Herts, but they have similar characters, and in at least one locality they contain the characteristic fossil.

At the south end of the Wolds they include a bed of hard whitish chalk like that seen elsewhere, but this does not recur, and in many places the whole band consists of soft grey laminated or shaly marl, often variegated with purple or brown. In some sections there is a medial bed of grey marly chalk, but this is not like the hard white chalk above mentioned. The lowest layer generally encloses numerous pebbles of hard chalk. This band of shaly marl varies in thickness from 1½ to 3 feet, and is a conspicuous feature in all the pits where it is exposed.

From analyses made of these marls by Mr. Meabourn Staniland and Mr. Grant Wilson† it would appear that the carbonate of lime varies in amount from 61 to 86 per cent., the siliceous or argillaceous ingredient varying inversely from 28 to 9 per cent.

STRATIGRAPHICAL DETAILS.

Zone of Ammonites varians.

A good section of the lower part of this zone is exposed in the quarry on the west side of the road half a mile north of Candlesby. Since 1877, when the section given in the Survey Memoir on Sheet 84 was taken, the pit has been cut further back, exposing 4 feet more of the platy chalk, so that it now reads :—

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* See Quart. Journ. Geol. Soc., Vol. xliv. p. 325, 1888.

† See Geology of East Lincolnshire; Geol. Survey Memoir, on Sh. 84, p. 38, 1887.

		ft.
Rubbly soil		1
Platy chalk with two of grey shaly marl		8
Whitish chalk, lumpy and irregularly bedded		14
Bluish-white chalk drying nearly white, called " the blue course "		3
Inoceramus Beds.	Massive grey gritty chalk in two courses, with shaly marl at base	4
	Hard nodular grey chalk, with layer of shaly marl at base	1
Sponge Bed—hard nodular pink and yellow rock		2
Layer of red marl (persistent).		
Gault—red limestone with marly partings		6½

The upper beds of this zone are seen below the Totternhoe Stone in a neighbouring quarry to the north-west, opposite the Cross Keys Inn.

Other good sections of the lower beds are found in the quarry north-east of Grebby Hall, and in another pit half a mile north-west of Dalby Church. In the latter the Sponge Bed is in two courses, and is 2 feet 9 inches thick. The *Inoceramus* Beds are over 5 feet thick, and 13 feet of the overlying beds are exposed.

A quarry east of this at the junction of the roads south of Dexthorpe exposes still higher beds, being about 20 feet deep and just touching the *Inoceramus* Beds at the bottom.

The basement beds are also visible in the deep valley east of Swaby, where a quarry shows :—

		ft.
Greyish-white chalk in irregular beds		8
Inoceramus Beds—hard grey gritty chalk full of *Inoceramus* shell		4
Sponge Beds.	Very hard nodular yellowish chalk	1½
	Hard lumpy yellowish-red chalk with cylindrical bodies	2½
Parting of dark red clay.		
Gault—brick-red limestone in regular beds		4

It will be noticed that the basal yellow limestone or " Sponge Bed " is here unusally thick (4 feet).

Another good section of these beds is exposed by the cutting at the west end of the tunnel near Withcall, on the Louth and Lincoln line.

In North Lincolnshire there are not many exposures, but the lower beds above the Red Chalk are seen in a quarry above the Hospital at Worlaby, N.N.E. of Brigg.

Exposures at Thorpe-le-Mire, north-east of Market Rasen, show how constant these several subdivisions are. Mr. Strahan saw the following beds in a quarry north-east of the village :—

	ft.
Grey lumpy or knotty chalk with thin shaly partings at intervals	8
Coarse grey irregularly bedded chalk	4
Beds concealed by talus, about	6
Selbornian.—Red Rock exposed at bottom	1

The beds hidden in the quarry are exposed in a neighbouring ravine, and consist of the following :—

		ft.
Inoceramus Bed.—Grey chalk with *Inoceramus* shells		3
Sponge Bed.	Pale yellow nodular chalk with pale red spots	1
	Red and yellow mottled nodular chalk	1
Selbornian.—Deep red nodular chalk		3

Zone of Offaster sphæricus.

The following are some of the most important exposures in this zone, beginning near Welton.

A quarry by the Cross Keys Inn, south of Welton Windmill, shows the following section :—

		ft.
Zone of *Offaster sphæricus.*	Thin-bedded rubbly chalk, with layers of buff-coloured shaly marl	10
	Very hard nodular grey chalk, with *Rhynchonella mantelliana* (Totternhoe Stone)	3
Zone of *Amm. varians.*	Hard greyish-white chalk in thin beds, with shaly partings	6
	Hard greyish-white chalk in beds about a foot thick	5
		24

The coloured bands of this zone first set in on the south side of the valley of the Calceby Beck, which traverses the Wolds by Calceby and South Thoresby. At the latter place there is a quarry in which a good section is exposed, as below :—

		ft.
Belemnite Marl—variegated marl in two layers, with a band of grey lumpy chalk between, lower layer red, buff, and green		1½
Pale pinkish-white chalk in one massive course		3
Hard yellowish-pink chalk in beds about a foot thick		7
Greyish-white chalk in thin beds with shaly partings		6
Hard compact greyish chalk in two beds		4
Layer of grey shale		
Hard cream-coloured chalk		4
Thin layer of soft yellowish marl		
Reddish marly chalk, with a band of chocolate-red marl in the middle, brick-red above and pink with grey lumps below		6
Layer of grey laminated marl		
Hard greyish gritty chalk, nodular and broken		2½
Totternhoe Stone.	Greyer and more compact chalk	1½
	Hard grey chalk with nodular crystalline lumps, some of which have yellow stains	3
		38½

There are several good sections of these beds in the numerous quarries at and near Louth. Thus there are two large quarries on the north part of the town west of the Union House, and they give the following combined section:—

			ft.
		Boulder clay and chalk rubble - - - - - - - -	10
		Middle chalk - - - - - - - - - - - - -	15½
Zone of *Offaster sphaericus.*		*Belemnite Marl*—soft grey and buff marl enclosing a band of marly chalk, and nodules of hard chalk at the base - - - - - - - - - - -	2½
		Hard white chalk resting on a thin seam of red marl -	2
		Hard pinkish chalk in thick even beds, with pink and yellow marly chalk at base - - - - - -	7½
		Greyish-white chalk, weathering into flattish lenticular lumps with marly layers - - - - - - -	12
		Hard greyish chalk forming one massive bed - -	4
		Hard greyish nodular chalk - - - - - - -	3
		Pink and grey chalk, passing down into light-red chalk with seams of red marl - - - - - - -	7¾
		Hard greyish nodular chalk - - - - - -	2¾
	Totternhoe Stone.	Compact grey gritty chalk - - - -	1½
		Hard nodular grey chalk, becoming platy below, with a thin layer of grey shale at the base - - - - - -	2½
		Hard greyish-white chalk in thick beds, with shaly partings -	10
			80

The upper part of the zone is exposed in a quarry on the London Road, south of the town, and the lower beds, including the Totternhoe Stone, in a pit by the Waterworks, one mile W.S.W. of the town.

There is also a very good section in a quarry at Hallington, two miles W.S.W. of Louth, where some extent of the Totternhoe Stone or "grey bed" is exposed. It is here 4 feet thick, and consists of:

	ft.
Hard grey chalk, open jointed, and breaking into blocks -	1¾
Grey nodular chalk with yellow stains and a layer of shale at the base - - - - - - - - - - - -	2¼

Above these are 13 feet of chalk, including the lower pink band, and below the Totternhoe Stone are 12 feet of greyish-white chalk.

The same succession can be seen in an old pit behind the lodge at the entrance to Welton Vale, 1½ miles west of Louth; and again at Withcall Station, on the Louth and Lincoln line. From the station these beds can be followed for some distance westward along the line, for though the dip is westward, the beds are broken by a succession of small faults with up-throws on the western side, so that the beds are repeated again and again. Another good exposure very like that at Hallington is shown in a quarry by Pan Holes Lane, E.N.E. of Donnington Station; the Totternhoe Stone is here 3½ feet thick, and the lower band of pink chalk is also exposed.

One of the pink bands (probably the lower one) has been seen in a pit on the road from Kirmond-le-Mire to Tealby, and again on the ridge to the south-east of Binbrook, but north of these places the colouring disappears. The extent of ground in a north-west and south-east direction, over which these coloured bands occur, is about 18 miles.

The equivalent of the Totternhoe Stone, with some thickness of the overlying chalk, is visible in a quarry at Grassby, a village about 3 miles north-west of Caistor. The dip is eastward, and the beds are broken by two faults, but the following succession can be measured:—

	ft
Greyish-white marly chalk, with buff-coloured marly bands	12
Hard rough nodular chalk - - - - - -	1
Grey shale and loose chalk - - - - -	½
Hard grey gritty stone, with large *Ammonites* and other fossils, and having a line of decomposed pyrite nodules at the base (Totternhoe Stone) - - - - - - -	3½
Hard greyish-white chalk in beds about a foot thick, with shaly partings - - - - - - -	8
	25

The higher beds of the Lower Chalk are exposed in the large quarry at South Ferriby, whence many thousand tons of chalk have been removed. This quarry is about 75 feet deep, and the section, as seen by Mr. W. Hill in 1887, is as follows:—

		ft.
	Middle Chalk (for details, see p. 484.) - - - - - -	45
Belemnite Marls.	Thin greenish-grey marly veins, enclosing whiter marly chalk - - - - - - - - - -	¼
	Smooth grey laminated marly chalk - - - - -	2
	Dark bluish-grey laminated marly chalk, variegated with lighter grey (*Act. plenus*) - - - - -	1
Zone of *Offaster sphæricus.*	Very rough nodular chalk, passing down into less rough whitish chalk - - - - - - -	2¾
	Hard whitish chalk in a massive course - - -	2½
	Greyish-white chalk, weathering into thin platy pieces along greenish marly veins - - - -	10

When I visited the pit in 1883 lower beds very exposed, viz.,

	ft.
Greyish-white chalk, as above - - - - - - -	3
Hard compact whiter chalk - - - - - - - -	2
Grey nodular chalk, with irregular seams of shale - - -	6

The Belemnite Marl.

At the southern end of the Wolds a quarry half a mile west of Welton shows at the top two layers of dark-grey marl, enclosing a course of hard whitish chalk.

They are seen again in a large quarry at Claxby, but here consist of one bed of grey marl, about a foot thick, and full of yellow-coated nodules of hard chalk.

In a quarry half a mile south-east of Calceby it consists of dull red laminated marl (18 inches), with 6 inches of rubbly marl below containing lumps of hard yellowish chalk.

At South Thoresby it has again a different aspect, being well exposed there in the western part of the quarry N.E. of the village; here it consists of variegated marl and chalk in three layers, each about 6 inches thick; the upper is a yellowish laminated marl; the middle consists of grey lumpy and marly chalk, the lowest of soft mottled marl, red, buff, and green.

Half a mile W.N.W. of Swaby it is 3 feet thick, and consists of pink shaly chalk above, passing down into mottled grey and purple marl, which has a basement layer of loose lumps of hard chalk. This rests on an undulating surface of the hard pink chalk below.

In Mr. Larder's quarry by the London Road, just south of Louth, the zone is represented by 18 inches of soft argillaceous marl, of a bluish-grey, variegated with red, and enclosing hard chalk pebbles at the base. On the north side of Louth, at Mr. Paddison's quarry, there are two beds of grey marl with a course of marly chalk between them (see p. 221).

To the westward near the main escarpment, and one mile E.S.E. of Gayton-le-Wold, a small pit exposes the following section:—

	ft.
Chalky soil and broken marly chalk - - - -	2½
Buff-coloured marl, with a band of chocolate-red marl in the middle and a layer of hard yellowish chalk pebbles at the base - - - - - - - - - - -	1½
Hard yellowish-white chalk, with thin seams of red and yellow marl - - - - - - - - - - -	5

In North Lincolnshire this horizon is exposed in two quarries near Caistor. One of these, three-quarters of a mile east of Nettleton Church, shows the following beds:—

		ft.
Middle Chalk.	Hard buff-coloured chalk, with shaly seams -	5
	Softer marly chalk - - - - - - - -	2½
Lower Chalk.	Soft laminated marl, light grey at top and bottom, with a purplish band in the middle (*Belemnite Marl*) -	1½
	Hard cream-white chalk in regular beds - - -	5
	Talus concealing lower beds - - - - - -	20

The other quarry is three furlongs south-east of Caistor, and the variegated marl is exposed at the bottom.

The section in the large quarry at South Ferriby has been given above, and here the zone of *Act. plenus* exhibits a more normal character, consisting of two marly bands with a course of grey marly chalk between them. Here, too, *Act. plenus* is not an uncommon fossil, whereas in the rest of Lincolnshire it is so rare that no specimen was found during the progress of the Survey.

FOSSILS FROM THE LOWER CHALK OF LINCOLNSHIRE.

This list is based on that given by Mr. W. Hill in the paper quoted, supplemented by such species as were collected by myself and by Messrs. Allen and Rhodes for the Geological Survey:—

—	Zone of Ammonites varians.	Zone of Offaster Sphæricus.	
		Totternhoe Stone.	Upper Beds.
Pisces.			
Scapanorhynchus raphiodon, *Ag.*	–	x	–
,, subulatus, *Ag.*	–	x	–
Ptychodus decurrens, *Ag.*	–	–	x
Cephalopoda.			
Ammonites [Haploceras] Austeni, *Sharpe*	–	x	–
,, [Acanth] navicularis, *Mant.*	x	–	–
,, [Pachyd.] *cf.* peramplus, *Mant.*	–	x	x
,, [Acanth.] rotomagensis, *d'Orb.*	–	x	–
,, [Schlœnb.] varians, *Sow.*	x	–	–
Turrilites scheuchzerianus, *Bosc.*	–	x	–
,, tuberculatus ? *Bosc.*	x	–	–
Actinocamax lanceolatus, *Sow*	–	x	–
,, plenus, *Blainv.*	–	–	x
Lamellibranchiata.		–	
Anomia sp.	x	–	–
Aucellina gryphæoides, *Sow.*	x	–	–
Exogyra conica, *Sow.*	x	x	–
,, haliotoidea, *Sow.*	–	x	x
Inoceramus latus, *d'Orb.* non *Mant.*	x	–	–
,, mytiloides ? *Sow.*	–	x	x
,, striatus, *Sow.*	x	–	
Lima echinata, *Eth.*	x	?	
,, globosa, *Sow.*	x	x	–
Ostrea curvirostris, *Nilss.*	–	x	x
,, acutirostris, *Nilss.*	–	–	x
,, vesicularis, *Lam.*	x	x	–
Pecten Beaveri, *Sow.*	–	x	–
,, fissicosta, *Eth.*	–	x	–
,, orbicularis, *Sow.*	–	x	–
Plicatula inflata, *Sow.*	x	x	–
Teredo amphisbæna, *Goldf.*	x	x	–
Brachiopoda.			
Kingena lima, *Defr.*	–	x	–
Magas pumilus ? *Sow.*	–	–	x
Rhynchonella Cuvieri, *d'Orb.*	?	x	–
,, mantelliana, *Sow.*	x	x	–
,, Martini, *Mant.*	–	x	–
,, lineolata, *Phil.*	–	–	x
Terebratula biplicata, *Sow.*	x	x	x
,, capillata, *d'Arch.*	–	x	–
,, semiglobosa, *Sow.*	x	x	x
,, sulcifera, *Morris*	–	x	–
Terebratulina nodulosa, *Eth.*	x	x	x

FOSSILS FROM THE LOWER CHALK OF LINCOLNSHIRE.—*contd.*

——	Zone of Ammonites varians.	Zone of Offaster Sphæricus.	
		Totternhoe Stone.	Upper beds.
Crustacea.			
Pollicipes sp.	–	x	–
Annelida.			
Serpula antiquata, *Sow.*	–	x	x
,, umbonata, *Mant.*	–	x	x
,, sp.	x	–	–
Echinodermata.			
Cidaris dissimilis, *Forbes*	–	x	–
,, *cf.* sceptrifera, *Mant.*	–	–	x
Discoidea cylindrica, *Lam.*	x	x	x
Goniaster (ossicles)	–	–	x
Holaster subglobosus, *Leske*	x	x	x
,, trecensis, *Leym.* (low var.)	x	–	x
Offaster sphæricus, *Schlüter*	–	x	x
Pseudodiadema variolare, *Brongn.*	x	–	–
Spongida.			
Brachiolites sp.	–	–	x

CHAPTER XIX.

THE LOWER CHALK IN YORKSHIRE.

General Description.

The Lower Chalk of Yorkshire is, on the whole, similar to that of Lincolnshire. It emerges from beneath the Humber at North Ferriby, and the level of its outcrop rises rapidly as it is traced to the north-west, till near Leavening it is about 600 feet above the sea. Its strike then begins to change, the anticline of the Vale of Pickering giving it an east and west direction, so that it runs eastward, and at the same time falls in level till it passes beneath the sea at Speeton.

The thickness of the Lower Chalk in Yorkshire varies considerably. Near South Cave it is about 72 feet; at the extreme north-west corner of the Wolds, near Leavening and Wharram, it is not more than 60 feet, and possibly less; while at Speeton it attains a thickness of 123 feet. It is evident, therefore, that a rapid diminution of thickness takes place from east to west.

Our knowledge of the Lower Chalk of Yorkshire, its limits, structure, and fossil contents, is due almost entirely to Mr. W. Hill, who followed up his revision of the Lincolnshire Chalk by a thorough examination of the Yorkshire Lower Chalk, and the details given in the following pages are taken chiefly from his excellent paper,* supplemented by some information from a paper by Professor J. F. Blake,† and from the Geological Survey Memoirs by Mr. C. Fox-Strangways.

Zone of Ammonites varians.—Along the main escarpment this zone has the same general aspect as in Lincolnshire. At the base there is a bed of hard white limestone, often tinged with pink or yellow, and often passing down into the Red Selbornian limestone, just as in some parts of Southern England Chalk Marl passes down into Upper Greensand.

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* Quart. Journ. Geol. Soc., Vol. xliv. p. 320, 1888.

† "On the Chalk of Yorkshire," Proc. Geol. Assoc., Vol. v. p. 232, 1878.

Above this limestone are beds of hard grey shelly stone (Inoceramus Bed), succeeded by some thickness of rough greyish nodular or lumpy chalk, which weathers into thin platy pieces.

Along the escarpment the thickness of this zone does not vary much, being apparently from 25 to 31 feet, but at Speeton it presents quite a different aspect, and one which recalls in some respects the more marly facies of the southern counties. Its thickness is at the same time increased to 77 feet, and some of the material is coloured pink.

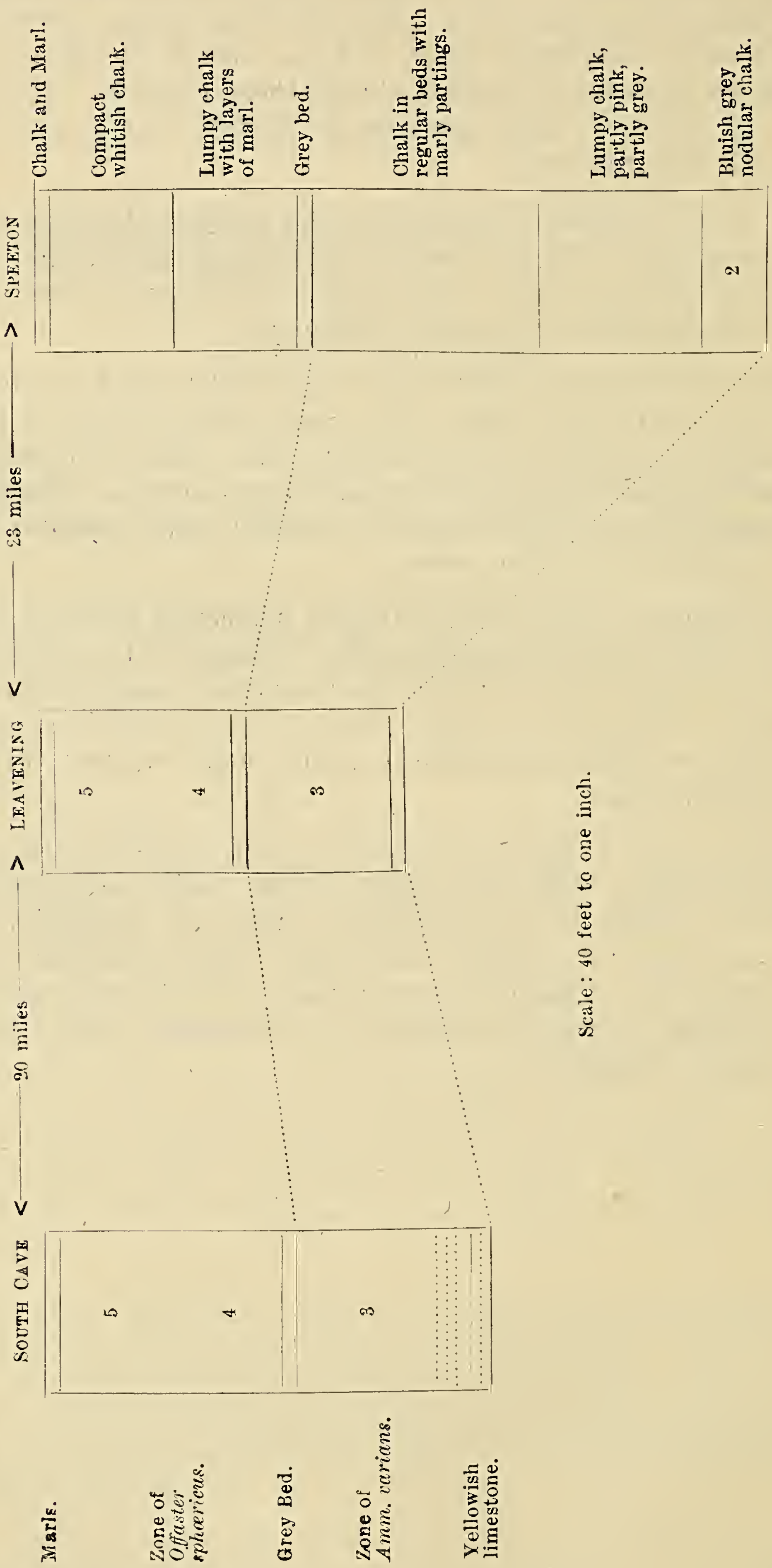
The zone of Offaster sphæricus also presents the same aspect as in Lincolnshire. At its base is a bed of grey shelly chalk, which is the continuation of the "grey bed" or Totternhoe Stone, and this is recognisable throughout Yorkshire.

Above the Totternhoe Stone there is generally 3 or 4 feet of hard chalk, and then softer chalk with much marly matter either in thin seams or around lumps of harder chalk. Part of these beds is often coloured red or pink, but is not always so coloured. The higher beds consist of hard whitish chalk in regular beds, weathering into platy or flattish lenticular pieces.

The thickness of the zone of *Offaster sphæricus* is about 40 feet at South Cave, and is probably rather thinner to the northward, but no complete section has yet been recorded near Leavening or Wharram. At Speeton its thickness is 44 feet, so that this portion of the Lower Chalk maintains a much more regular thickness than the lower part.

At the summit there is everywhere a thin representative of the Belemnite marl. Along the course of the main escarpment this seems to consist of two layers—a band of yellowish marly chalk, and a layer of soft grey marl below, often variegated in grey buff, and black. Although there can be no doubt about the correlation of these marls, no specimen of *Actinocamax plenus* has yet been found in Yorkshire.

The accompanying diagram shows the variations in the thickness of the two zones in different parts of Yorkshire:—


Chalk and Marl.
Compact whitish chalk.
Lumpy chalk with layers of marl.
Grey bed.
Chalk in regular beds with marly partings.
Lumpy chalk, partly pink, partly grey.
Bluish grey nodular chalk.
SPEETON
2
< 23 miles >
LEAVENING
5
4
3
< 20 miles >
SOUTH CAVE
5
4
3
Marls.
Zone of Offaster sphæricus.
Grey Bed.
Zone of Amm. varians.
Yellowish limestone.
Scale: 40 feet to one inch.

STRATIGRAPHICAL DETAILS.

Zone of Ammonites varians.

The first good section through these beds is to be found in the railway cutting east of South Cave. The following details were taken by Mr. Hill on the north side of the line, 200 yards east of the signal-box at Weedly Springs, and continued at the east end of the short tunnel:—

	ft.
"Grey Bed," or Totternhoe Stone (east of tunnel)	
Hard whitish chalk, rather rough - - - - about	20
Hard grey chalk, the lower part being gritty [or shelly] chalk, divided into courses by marl-bands - - - -	10
Compact yellowish white limestone, rather broken, but appearing to graduate into the Red limestone below - - -	1
	31

Very few natural exposures or quarry sections of the Lower Chalk occur along the escarpment between South Cave and Leavening, but the basement beds are exposed in a small pit in Garrowby Park, half a mile east of the hall.

A complete section through this zone is found in a slipped mass of chalk at Leavening, which shows:—

		ft.
Grey chalk (see p. 232 for details) - - - - - - -		19½
Zone of *Am. varians.*	Hard whitish chalk in fairly thick beds - - -	9½
	Seam of grey marl	
	Thin-bedded chalk, rather rough and nodular, weathering into thin platy pieces - - - - - - -	8
	Hard greyish gritty massively-bedded chalk (Inoceramus Bed) - - - - - - - - - - -	6
	Hard crystalline reddish-yellow limestone - - -	1
Selbornian. Red limestone with coarse sand below.		

There are pits near Wharram Grange by the railway near Wharram Station, on Scragglethorpe Brow, and at Knapton Wood, but the chalk at all these places is much broken, and partly obscured by talus, so that the succession could not be made out.

The upper portion of the Chalk Marl, rough, greyish-white, and weathering into platy pieces, is exposed on the slope of the deep combe west of Ganton Hall. Between 20 and 30 feet are visible, and Mr. Blake remarks that in this neighbourhood the Red Chalk (Selbornian) crops out near the 200 feet contour level, while chalk with *Inoceramus mytiloides* is seen at 450 feet, so that the thickness of Lower Chalk here may be as great as at Speeton.

We now come to the cliff section on the coast east of Speeton Gap, the section commencing about half a mile east of the mouth of Speeton Beck, near a spot marked on the Ordnance map as

Nanny Goat's House, and extending for about a mile eastward, though the lower beds are frequently concealed by talus and fallen masses.

This section has been described by several writers, notably by Mr. Wiltshire,* Dr. Barrois,† Mr. J. F. Blake,‡ and Mr. W. Hill,§ but Mr. Hill's is the only complete account of the Lower Chalk of Speeton, because no one had previously fixed its upper limit. As to the succession of the lower beds, Mr. Wiltshire, Dr. Barrois, and Mr. Hill are in close agreement, but here again the last was the first to recognise the representative of the Totternhoe Stone or "grey bed," which fixes the summit of the *Am. varians* zone.

The following account of the beds below this horizon is compiled from that given by Mr. Hill, but the numeration of the beds is mine, Bed 1 corresponding with his 2, and Bed 2 with the lower part of his 3, which I have subdivided. Dr. Barrois' thicknesses are also given to show how closely they correspond with Mr. Hill's :—

		Hill. ft.	Barrois. ft.
	The Grey Bed (see postea p. 233).		
Zone of *Am. varians.*	4. Bedded grey chalk, the upper part in beds about 2 feet thick with marly partings, the lower beds more nodular and rougher from the abundance of comminuted shell-fragments - - - - - - - -	39	+32
	3. Nodular marly chalk, with lenticular layers of smoother chalk; the upper 2½ feet coloured pink, the lower 7½ feet grey	10	13
	2. Nodular marly chalk, the upper 10 feet having grey lumps in a matrix of pinkish marl, the lower 8 feet being wholly of a brick-red colour - - - - - -	18	15
	1. Bluish-grey nodular chalk, with marly bands containing *Bel. minimus* near the base - - - - - - - -	10	10
	Red Chalk (Selbornian).		
		77	+70

Mr. Hill observes that ordinarily only 5 feet of Bed 1 are visible at the base of the cliff, but that occasionally the whole of it is exposed, and it can then be seen to pass down into smooth red chalk.

The above succession is different from that seen anywhere else in Britain; the well-marked courses of hard white or pinkish chalk (Sponge Bed) and of hard shelly stone (Inoceramus Bed), which are constant all through the Wolds of Lincolnshire and Yorkshire, cannot be distinguished at Speeton. Mr. Hill, however, remarks that the beds above numbered 1, 2, and 3 are comparable in general characters with the Chalk Marl of Cambridge, Suffolk, and South

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* Geologist, Vol. ii. p. 261, 1859. Also reprinted for the Geologists' Association.

† Recherches sur le Terr. Crét. Sup., 1876, p. 194.

‡ Proc. Geol. Assoc., Vol. v. p. 232 (1878).

§ Quart. Journ. Geol. Soc., Vol. xliv. p. 343 (1888).

Norfolk, that *Avicula gryphœoides* is a common fossil in them, as it is also in the Sponge Bed and in the lower beds of Chalk Marl in the counties above mentioned; lastly, that at the base of Bed 4 there is a great increase in the quantity of shell fragments. From this evidence he concludes that Beds 1, 2, and 3 (with a combined thickness of 38 feet) are an expansion of the Sponge Bed, just as we saw reason to conclude that in Norfolk the Sponge Bed is a condensation of some 25 feet of the Chalk Marl proved at Stoke Ferry; he also thinks that the lower part of Bed 4 corresponds to and is an expansion of the Inoceramus Bed.

With respect to the colour-bands, both Mr. Blake and Mr. Hill have pointed out that they are not restricted to definite stratigraphical horizons, but that even within short distances the red colour dies out of one and reappears in a different bed. Thus the red colour at the base of Bed 2 "forms an undulating line which does not coincide with the plane of stratification." Again, near Nanny Goat's House the whole of Bed 4 is grey, while there is 6 feet of pink chalk *above* the Grey Bed (in Mr. Hill's Bed 5). A mile further east, where this bed comes down to the beach, there is no red colour in No. 5, but 8 feet of the chalk below the Grey Bed is coloured pink; moreover, a little further east there is no colour at either horizon.

Zone of Offaster sphæricus.

The first good section in South Yorkshire is afforded by the cutting on the Hull, Barnsley, and West Riding Railway. The following succession was taken by Mr. W. Hill on the south side of the line, about 400 yards west of Sugar Loaf Hill:—

	ft.
Rather hard whitish chalk, weathering in platy pieces, in courses divided by seams of marl - - - - - -	23
Hard chalk, whitish above, greyish below, with a grey marl band at the base (fossils) - - - - - - -	1¼
Hard whitish chalk, weathering into rough platy fragments, divided into courses by marly seams - - - -	6
Softer marly chalk, rather nodular, bedding indefinite, stained a bright pink - - - - - - - - - -	4
Hard rough whitish chalk - - - - - - -	3
Totternhoe Stone.—Hard grey nodular chalk, becoming platy below, with green-coated nodules at base - - -	1½
	38¾

Mr. Hill obtained many fossils from the Totternhoe Stone or "Grey Bed," and he remarks that "large Ammonites are common as usual at or just above the horizon of the 'Grey Bed,' and I left one in the cutting 1 foot 8 inches in diameter."

The next good exposure of these beds is near Park Farm, Londesborough. Of this Mr. Hill says:—"I hardly think the chalk seen here is in its natural order; most of the higher beds seemed to me to be slipping over the lower ones. . . . The central part seemed fairly solid and continuous. I give the following section for what it may be worth:—

	Feet.
Rubbly chalk and soil with marked indications of the Belemnite marls at the base	2–3
Face obscured by talus, chalk appeared broken up [and has probably slipped]	10–12
Hard roughish chalk, weathering into platy pieces, thin marl bands	3
Rather soft marly pink chalk	$3\frac{1}{2}$
Hard rough chalk, with green-grey marl bands	5
Totternhoe Stone.—Hard grey chalk, rather nodular, with green-coated nodules at the base (fossils)	$1\frac{1}{2}$
About	27

The marly pink band is seen again in Uncleby Dale, but there is no clear section.

The Totternhoe Stone and some of the overlying chalk is exposed in the slipped mass at Leavening above the Chalk Marl (see p. 229). The details given by Mr. Hill are as follow:—

	ft.
Chalk rubble, much broken up	6
Whitish chalk, not hard, much broken, but apparently in place, irregularly bedded, with strongly marked buff-coloured bands of marl	9
Whiter chalk, less marly than hard	$2\frac{1}{2}$
Grey Bed.—Hard grey nodular chalk, clearly distinguishable from that above and below	2
	$19\frac{1}{2}$

No pink-coloured chalk was seen here, but a yard or two beyond the point where the section ends, rubble of pink chalk is seen; its exact position in the section, however, was not determinable. Pink chalk overlying greyish chalk is also seen about a quarter of a mile east of Swinham.

Mr. Hill thinks that the thickness of the *Off. sphæricus* zone in this district is about 35 feet, but there is no means of measuring exactly. Eastward, along the northern brow of the Wolds, it becomes thicker, and a fairly good section of it is exposed in the side of the combe west of Ganton Hall. The succession is given as follows:—

		ft.
	Middle Chalk, zone of *Inoc. mytiloides*, - seen for	8–10
Zone of *Off. sphæricus.*	Thin-bedded platy chalk, much covered by *débris*, and seen only at intervals	38
	Pinkish-red chalk, rather soft and marly	4
	Rough chalk with marly bands	6–8
Zone of *Am. varians.*	Hard lumpy chalk, darker grey than the above	2
	Rough greyish-white chalk, weathering into platy pieces	+20

Mr. Hill did not recognise the Totternhoe Stone here, but it should occur a few feet below the pink chalk. Some of the beds seem to have slipped a little out of place.

Lastly, there is the fine section of the Speeton cliffs, of which the following account is compiled from that given by Mr. Hill :—

The first course above the Chalk Marl, from which it is separated by a layer of grey marl 3 inches thick, is a bed of grey chalk 2 feet thick, rather nodular and hard. This is the "Grey Bed" or Totternhoe Stone, and is markedly greyer than the beds above and below. It can be followed from Nanny Goat's House, with the dip of the beds to the south-east to the point where it disappears below the beach. It retains its solid appearance, and does not break up under the influence of weather or of waves ; but the lower 6 inches splits readily into flakes and graduates into the underlying layer of marl. It contains *Pecten orbicularis*, *Holaster subglobosus*, *Lima echinata*, and other fossils, but they are not in a good state of preservation.

For 20 feet above this bed the chalk is very hard and nodular or lumpy ; the lumps are separated by marly material, and the whole is divided into beds by strongly marked marl bands. The marly part is generally of a bluish or greenish colour, but at Nanny Goat's House the lowest 5 or 6 feet are coloured pink. Eastward, however, this colour band passes to a lower horizon.

Above this chalk is a 3-feet bed of greyish-buff chalk with darker grey veins and streaks. It weathers out along the cliff as a massive and solid bed, and is separated from the chalk below by a layer of marl, in which *Ostrea vesicularis*, *Terebratula biplicata*, and *Ter. semiglobosa* are very abundant.

To this succeeds 19 feet of hard, white, fairly smooth chalk divided into regular courses by thin seams of shaly marl. The total thickness of this zone at Speeton is therefore 44 feet.

The Belemnite Marl.

Inland, along the course of the main escarpment, this bed seems to consist entirely of grey marl and yellowish marly chalk generally in two courses only, but at Speeton it has the Midland facies of two marly layers separated by a course of hard, white chalk.

The first place north of the Humber where these beds are exposed is the Greystones Pit, three quarters of a mile north of Melton. Most of the face is obscured by talus, but near the top there is a band of laminated marl, almost black in the centre, dark grey at the top and bottom.

The next exposure is in the railway cuttings east of South Cave, and the Belemnite Marls come down to the level of the line, about 85 yards west of the bridge near the entrance to the tunnel under Sugar Loaf Hill, where the section, as described by Mr. Hill, is:—

		ft.	in.
	Middle Chalk	13	0
Belemnite Marl.	Soft yellowish marly chalk, enclosing lenticular beds of harder chalk	1	9
	Soft grey marl, variegated bluish-grey and buff in upper part, nearly black in middle, and greyish-buff below	1	4
	Rough nodular chalk, consisting of harder lumps embedded in greenish-grey marl, passing down into hard white chalk.		

A section almost exactly similar in its details, except that each of the marly beds is 18 inches thick, is exposed in a pit about a mile and a half south-east of Londesborough by the road leading from Towthorpe Corner to Easthorpe (for this see p. 232). There are probably other exposures of it in some of the Wold valleys, but none have come to our knowledge.

Mr. Fox-Strangways was informed by Mr. J. R. Mortimer, of Driffield, that this marly band was formerly seen in the section near Wharram Railway Station.*

In the Speeton cliff section the Belemnite marls consist of the following beds, which form a conspicuous band along the cliff face between the hard beds of the Lower and Middle Chalk:—

		ft.	in.
	Bedded chalk without flints	7	6
Belemnite marls	Variegated shaly marl, bluish-grey and buff		4–6
	Hard smooth white chalk	1	0
	Shaly argillaceous marl, grey above and below, almost black in the middle	0	9

In the above account, the several parts of the Speeton section have been described under the zonal headings, but a summary of the complete succession of the beds forming the Lower Chalk in the Speeton cliffs may now be given:—

		ft.
Zone of *Off. sphæricus*	Belemnite Beds (as above)	2
	Compact whitish chalk in regular courses, the top course rubbly, the rest smooth and even	19
	Massive bed of grey and white streaky chalk	3
	Rough nodular chalk, divided into courses by seams of greyish marl	20
	Totternhoe Stone or "Grey Bed"	2
Zone of *Am. varians*	Rough grey chalk in beds about 2 feet thick, with marly partings	39
	Nodular and marly chalk (partly pink)	10
	Nodular marly chalk, grey and red	18
	Bluish-grey nodular chalk, with marly seams	10
		123

Fossils from the Lower Chalk of Yorkshire.

The following list is taken from those given by Dr. Barrois and Mr. W. Hill in the publications already referred to, with a few additions and corrections:—c=South Cave cutting. s=Speeton. o=other places.

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* Geology of the Country around Driffield, Mem. Geol. Survey, 1886, p. 9.

	Zone of Ammonites varians.			Zone of Offaster Sphæricus.					
				Grey Bed.			Upper Beds.		
Fish teeth		s		c	s				
Cephalopoda.									
Ammonites [Acanth.] laticlavius, *Sharpe*								s	
,, [,,] rotomagensis, *Brongn*	c			c					
,, [Schloenb.] varians, *Sow.*		s							
,, sp.		s					c	s	o
Baculites baculoides, *Sow.*		s							
Turrilites tuberculatus, *Bosc.*	c ?		o						
Belemnites minimus, *Lister*		s							
Actinocamax lanceolatus ? *Sow.*				c					
Lamellibranchiata.									
Aucellina gryphæoides, *Sow.*		s	o						
Avicula lineata, *Rosmer*						o			
Inoceramus Cuvieri ?, *Sow.*		s					c	s	o
,, latus, *d'Orb.* (non *Mant.*)	c	s		c	s				
,, striatus, *Sow.*		s							
Lima echinata, *Eth.*		s		c	s				
,, globosa, *Sow.*				c					
Ostrea vesicularis, *Lam.*	c	s	o	c	s	o		s	
Pecten orbicularis, *Sow.*				c	s	o			
Plicatula inflata, *Sow.*		s	o	c	s				
Spondylus dutempleanus, *d'Orb.*							c		
,, striatus, *Sow.*		s					c		
Brachiopoda.									
Kingena lima, *Defr.*	c	s	o		s				
Rhynchonella grasiana, *d'Orb.*					s				
,, lineolata, *Phil.*		s	o						
,, mantelliana, *Sow.*		s			s				
Terebratula biplicata, *Sow.*	c	s	o	c	s	o		s	o
,, ,, var. faba, *Sow.*		s							
,, semiglobosa, *Sow.*	c	s	o	c	s	o	c	s	c
,, ,, var. subundata, *Sow.*		s							
,, squamosa, *Sow.*		s							
,, sulcifera, *Morris*		s							
Terebratulina triangularis ? *Eth.*	c	s	o	c	s	o		s	
,, nodulosa, *Eth.*		s			s				
Crustacea.									
Glyphæa cretacea ? *McCoy*	c								
Annelida.									
Serpula antiquata, *Sow.*	c	s		c	s				
,, umbonata, *Sow.*		s			s				
Echinodermata.									
Cidaris dissimilis, *Forbes*		s							
,, vesiculosa, *Goldf.*		s			s				
Cyphosoma sp.		s							
Discoidea cylindrica, *Lam.*	c	s	o	c			c	s	o
Holaster lævis, *de Luc.*		s							
,, subglobosus, *Leske*	c	s	o		s		c	s	o
,, trecensis ?, *Leym.*		s ?							
Offaster sphæricus, *Schlüter*		s						s	o
Peltastes stellulatus, *Ag.*		s							
Pseudodiadema sp.		s							

CHAPTER XX.

THE EQUIVALENTS OF THE LOWER CHALK IN THE NORTH-EAST OF FRANCE.

French Nomenclature.

The divisions of the Chalk in France were studied in some detail much earlier than they were in England. The stratigraphical explorations of d'Archiac, Buvignier, and Leymerie between the years 1838 and 1850, together with the systematic study of Cretaceous fossils by d'Orbigny between the same dates, laid the foundations of the classification which has been adopted in France.

The French have never been hampered by the idea of the lithological unity and indivisibility of the Chalk which led many English geologists to resist the innovation of dividing it into stages. Their country is larger, and it includes a wider and more varied series of Cretaceous strata deposited under different physical and bathymetrical conditions. Moreover, their classification had the advantage of being based on the evidence of fossils obtained from many different parts of France, and studied at the same time by the acute palæontologist Alcide d'Orbigny.

Up to the year 1843 the different portions of the French Chalk were known by lithological names, just as they were in England —namely, *craie blanche, craie tufau*, and *craie chloritée.* But in a paper reviewing the distribution of the Cretaceous Cephalopoda and Gasteropoda,* d'Orbigny proposed the name *Senonien* for the white or Upper Chalk, taking it from the location of the Gallic tribe of Senones (Sens in Yonne), and the name of *Turonien* for the *craie tufau* and *craie chloritée*, taking it from the tribe of Turones (at Tours), and the province Turonia (Touraine).

Thus, at first, he only recognised two stages in the Chalk, which roughly corresponded with what were at the same time called Upper Chalk and Lower Chalk in England. Between 1847 and 1852, however, he became aware that the group which he had called *Turonien* contained two distinct assemblages of species. He saw that his original *Turonien* should be separated into two stages. Accordingly he restricted that name to the upper portion, and proposed a new name, *Cenomanian*, for the lower portion, taking it from the ancient name of the town of le Mans (Cenomanum), where a certain type of these lower beds was well developed and highly fossiliferous.†

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* Bull. Soc. Géol. de France, Ser. 1., Vol. xiv. p. 480 (1843).

† Cours Elementaire de Géologie, etc., Vol. iii. (1852) p. 631.

D'Orbigny points out that his Cenomanian stage consists of quartzose sand in Sarthe and Loire, of " craie chloritée " (chalk with glauconite grains), in Normandy and the Pay du Bray, of compact or marly white chalk in the Aube Yonne and north-east of France; and he remarks, " it is easy to see from these great differences at one and the same geological horizon what conclusions we should reach if we relied on mineralogical characters to distinguish the Cretaceous stages ; that differences of opinion and of classification should exist cannot astonish us ; but when we abandon that deceptive character and substitute for it, as we have done, palæontological characters, everything will be simplified ; horizons will show themselves clearly, and we shall see the stratigraphy agreeing accurately everywhere with the palæontological results." (*Op. cit.*, p. 638.)

Things are not quite so simple as d'Orbigny supposed they would be, and his stratigraphic correlations are not all correct, but he was unquestionably right in believing that the palæontological method would give better results than a purely stratigraphical or lithological method. In this he was only carrying out the dictum of William Smith that " strata can be identified by the fossils they contain."

The following are the Cephalopoda and some of the other fossils given by d'Orbigny in 1852 as characteristic and widely distributed members of his Cenomanian fauna :—

Belemnitella vera (=plena).
Nautilus triangularis.
Ammonites varians.
  ,, falcatus.
  ,, rotomagensis.
  ,, Mantelli.
Scaphites æqualis.
Baculites baculoides.
Turrilites costatus.
Avellana cassis.
Arca passyana.
Corbis rotundata.
Inoceramus striatus.
Pecten asper.
  ,, elongatus.
Pecten (Neithea) æquicostata.
Spondylus striatus.
Discoidea cylindrica.

Everyone will recognise these as species which are characteristic of our Lower Chalk (including Chloritic Marl) ; none of them range above it, and though some of them do range downward into a bed which we class as Upper Greensand, yet that bed is only a few feet thick, and may be regarded as a passage bed.

Some French geologists now include the whole or a part of the zone of *Ammonites rostratus* in their Cenomanian, but the propriety of such an arrangement does not concern us here, for in this chapter we are dealing with the French equivalents of our Lower Chalk and not with any particular conception of the Cenomanian stage.

Stratigraphical Details.

Boulonnais.—The only coast section of the Chalk in the north-east of France is that of Blanc-nez, which corresponds to that of Kent, near Dover. This has been described by M. Chellonneix and Prof. Barrois, and the following account of it is adapted from that of the latter*:—

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* Proc. Geol. Assoc., Vol. vi. pp. 28, 29 (1879).

	Ft.
Zone of Belemnites plenus.—At the top is a bed of pale green marl 2 feet thick ; the chalk below is at first greyish, but passes down into hard whitish chalk - - - - - -	66
Chalk of Ammonites rotomagensis.—Compact grey marly chalk - - - - - - - - - - - -	66
Chalk of Ammonites varians.—Chalk marl, more or less argillaceous, with a nodular bed at the base full of *Plocoscyphia mœandrina* and *Pl. fenestrata* - - - -	50
Chloritic Marl (*zone of Ammonites laticlavius*).—The upper part is a sandy chalk marl with green grains, the lower part a dark green marly sand, full of phosphatic nodules (many fossils, some phosphatic, some not) - - - - - -	10
	192

It will be seen that this succession corresponds very closely with that of Dover (see p. 37), but is somewhat differently divided.

The Chloritic Marl or zone of *Am. laticlavius* is identical with our zone of *Stauronema Carteri.* The "Chalk of *Am. varians*" corresponds with Beds 2, 3, 4, 5 of our Dover section. The "Chalk of *Ammonites rotomagensis*" appears from the thickness assigned to it to correspond with our Beds 6 and 7, but as Dr. Barrois records *Am. varians* from it, some of our Bed 5 may also be included in it. The following fossils are mentioned as occurring in this 66 feet:—

Ammonites varians.
,, rotomagensis.
,, Austeni.
Ostrea vesicularis.
Pecten orbicularis.
Plicatula inflata.
Inoceramus virgatus, (=striatus).
Rhynchonella mantelliana.
Serpula umbonata.

Holaster subglobosus.
Hemiaster Morrisii.
,, Griepenkerli.
Cidaris vesiculosa.
Echinocyphus difficilis.
Peltastes clathratus.
Pseudodiadema ornatum.
,, pseudo-ornatum
,, Michelini.
,, variolare.

The description of the highest subdivision called by Prof. Barrois the zone of *Belemnites plenus* answers exactly to our Beds 8 and 9. It appears, however, to be much more fossiliferous on the French side, and M. Chellonneix has given a long list of fossils obtained from the whitish chalk by Dr. Robbe and himself. Among them are the following:—

Cerithium luschitzianum.
Solarium Gosseleti.
Pecten orbicularis.
Inoceramus striatus.
Exogyra haliotoidea.
Ostrea canaliculata.
Terebratula semiglobosa.
,, squamosa.
Kingena lima.

Rhynchonella grasiana.
,, Martini.
,, mantelliana.
Terebratulina rigida.
Teredo amphisbæna.
Vermicularia umbonata.
Hemiaster bufo.
Micrabacia coronula.
Onchotrochus serpentinus.

This assemblage is such as might be found in our Chalk Marl, and we cannot help expressing some doubt as to their having all come from the higher beds. We give the list because Prof. Barrois has quoted it, but we think it requires confirmation.

The Wissant type of Cenomanian can be followed all round the Boulonnais, but the total thickness probably diminishes somewhat to the southward.

Country of the Tourtias—Pernes, Mons, and Tournay.—Passing over the Chalk country south-east of the Boulonnais we find the Cenomanian cropping out again in the country to the south-west and south of Bethune. This region has been described by Mons. H. Parent.* His identification of a zone of *Pecten asper* overlain by a zone of *Ammonites laticlavius* has been mentioned in the first volume of this Memoir, and whether the latter or the former is regarded as the basement bed, it would seem that there is near Pernes and Matringhem a Lower Chalk similar to that of Folkestone and Wissant, but much diminished in thickness. The section at Pernes is as follows :—

	ft.	in.
6. Compact marly chalk - - - - - - - -	4	0
5. Marly chalk, slightly shaly and glauconitic - - -	2	6
4. Marly glauconitic sand - - - - - - - -	2	6
3. Sand with more glauconite - - - - - - -	3	4
2. Greensand with many phosphatic nodules - - -	2	0
1. Brownish clay, slightly glauconitic, resting on the upturned Devonian - - - - - - - - -	2	6
	16	10

Of these beds M. Parent refers 5 and 6 to the zone of *Holaster subglobosus,* 3 and 4 to that of *Ammonites laticlavius ;* No. 2 is his zone of *Pecten asper,* which we have already accepted as such; the fauna of No. 3 is certainly that of the Chloritic Marl of the Isle of Wight, for in it occur *Ammonites varians, A. Coupei, A. Mantelli, Turrilites Morrisi, T. tuberculatus, T. costatus, Baculites baculoides, Nautilus deslongchampsianus, N. lævigatus,* and *N. largilliertianus,* with many other fossils.

As regards the higher part of the stage M. Parent says : "I have only observed the upper part of the zone of *Hol. subglobosus* at a few spots ; to the north of Houdain it occurs as a chalky marl with *Rhynchonella mantelliana, Rh. grasiana, Kingena lima, Plocoscyphia mæandrina.* At Pernes, on the road from Bailleul-les-Pernes there is a marly chalk containing *Holaster trecensis, Inoceramus virgatus* (*striatus, Sow.,*) and *In. orbicularis* (*latus,* d'Orb), which I refer to this zone."

Of the zone of *Belemnitella plena* he says : "The only place where I have seen the marl with *Belemnites plenus* characteristically developed is near Fauquembergne ; it forms part of the hill which rises to the east of the village, and contains *B. plenus* at the base. It occurs again in a gully to the left of the road from Fruges, and at 'Bout de la Ville' in a quarry."

The most easterly quarry described by M. Parent at Aix-en-Gohelle shows a curious and significant section, as follows :—

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* Ann. Soc. Geol. du Nord, Tom. **xxi.** p. 205 (1893).

	ft.	in.
3. Whitish marly glauconitic chalk, resting irregularly on the bed below - - - - - - - seen for	3	6
2. Glauconitic sand, with many phosphatic nodules and some pebbles at the base, which rests on an eroded surface of No. 1 - - - - - - - about	1	0
1. Yellowish-grey clay, with some glauconitic layers, containing many pebbles of older rocks, and piped into the underlying Devonian schists - - - - - - 1 to	1	6

The highest bed here is identified as the zone of *Belemnites plenus,* and this species, together with *Nautilus subradiatus,* occurs in the glauconitic sand below, which he appears to regard as a thin littoral representative of the zone of *Holaster subglobosus.* As *Terebratula tornacensis* is particularly abundant in this sand, M. Parent calls it "les sables a *T. tornacensis.*"

Passing still farther east to the country between Valenciennes and Tournay and Mons, on the borders of Belgium, we enter the typical region of the Tourtia rendered classical by the memoirs of d'Archiac, Dumont, and Messrs. Briart and Cornet. *Tourtia* is a name given by the miners to all the loose sands and sandy marls which rest on the surface of the Palæozoic rocks. These beds differ much in character and fossil contents at different places, and many attempts have been made to distinguish different horizons and to correlate the "*Tourtias*" of different localities.

It can hardly be said that the classification of the Tourtias is yet settled, but Professor Barrois has given reasons in his "Terrain Crétacé des Ardennes" (1878) for regarding the Tourtia de Mons as the equivalent of his zone of *Belemnites plenus—i.e.*, as representing the upper part of the Lower Chalk. In the northern part of the area this marl with *Bel. plenus* rests directly on the Palæozoic rocks, but further south beds come in between them (the Tourtia de Montignies) which he refers to the zone of *Pecten asper ;* and in 1878 he was of opinion that the zone of *Holaster subglobosus* was unrepresented in this Department (*Op. cit.*, p. 368). He admitted, however, on p. 348 that there is a general analogy between the fauna of the Tourtia de Montigny and that of the Grès du Maine, and he has informed me that he now agrees with M. Parent, who in 1893 suggested that this Tourtia, like the Greensand of Aix-en-Gohelle, was a littoral representative of the zone of *Hol. subglobosus.* *

Recurring, however, to the views expressed by Professor Barrois in 1878, he was then of opinion that the zone of *Hol. subglobosus* was absent not only in the Nord, but also throughout the Departments of Aisne and Ardennes, yet he identifies everywhere a "niveau à *Ammonites laticlavius,*" as forming the upper part of his zone of *Pecten asper.* Consequently he assumed that the highest and the lowest zones of what he calls the "Cenomanien Superieur" are constant and continuous throughout the east of France, but that the beds which correspond to our Chalk Marl and Grey Chalk thin out and disappear as they pass toward the Palæozoic ridge.

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* Still more recently M. J. Cornet has described (Ann. Soc. Geol. de Belg. T. xxviii. p. 53) the beds traversed by some new shafts near Mons, which have disclosed beds of glauconitic sand between the Tourtia de Mons and the Meule de Bracquegnies ; these contain *Am.* [*Schl.*] *varians*, *Am.* [*Acanth.*] *rotomagensis*, *Inoceramus striatus*, *Pecten asper*, and other fossils. They appear to represent the zone of *Am. varians.*

Such a stratigraphical arrangement is certainly possible, but it is not that which would *à priori* be most probable. The epoch of the Cenomanian in the Anglo-Parisian basin is admitted by all geologists to have been one of gradual and continued subsidence, which permitted the waters of the Cretaceous sea to spread farther and farther over the surrounding land. Dr. Barrois offers no evidence for the idea of any local interruption of this subsidence in the middle of the Cenomanian epoch; and if there was no such interruption, the mode of thinning would most probably be by overlap.

As the Département du Nord presents a special attenuated and evidently shallow water type of the Cenomanian, and as the zones of the deep water English and Boulonnais type cannot be traced continuously into the Ardennes, we think that the relations of the Tourtias will be better understood if they are approached from the south. We shall therefore first give the succession to be found in the Departments of the Yonne and the Aube, where a deep-water facies presents itself, very similar to that of southern England. From this region the stratigraphical changes can be traced northward along the outcrop which runs through the Departments of the Marne, Ardennes, and Aisne.

It must be understood that in the following account we have taken Professor Barrois' memoirs* as our chief guide for the stratigraphical facts, but shall assume that the zonal correlation of the beds is open to revision and correction. On this some remarks will be made in the sequel.

Departments of Yonne, Aube, Marne, and Aisne.—Commencing, therefore, in the Yonne we find the Cenomanian presenting a fair thickness (about 100 feet), and lying between well-defined limits; for its basement bed rests on the marly clays of the zone of *Ammonites inflatus* (Upper Gault), while above it is the hard nodular chalk which forms the zone of *Inoceramus labiatus* (Turonian).

The succession is well exposed near Saully, and is given by Professor Barrois as follows:—

	ft.
Compact greyish-white chalk with grey flints, *Am.* [*Acanth.*] *rotomagensis* - - - - - - - - -	60
Grey sandy marl with some fossils - - - - -	16
Thin layer of sandy glauconitic marl, with phosphatic nodules (a few inches).	
Gault.—Black marly clay with septaria (zone of *Am. inflatus*).	

Professor Barrois did not find fossils in the nodule bed above the Gault, and there is therefore no ground for identifying it with any particular zone: it is simply the basement bed of the Chalk, like that at Burham in Kent. The overlying marl contains *Pecten asper*, *Rhynchonella grasiana*, and *Micrabacia coronula*, and is referable to the lower part of our Chalk Marl (zone of *Am. varians*).

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* La Zone à Belemnites plenus, Ann. Soc. Geol. du Nord, T. ii. p. 147 (1875); and Le Terrain Crétacé des Ardennes, Ibid., Tom. v. p. 227 (1878).

Professor Barrois does not mention any sections in the Aube, but the Lower Chalk of that department has been described by M. Peron,* who makes the thickness about 150 feet and the succession as follows :—

3. Dry whitish chalk, with *Scaphites œqualis.*
2. Massive chalk, with *Holaster nodulosus.*
1. Marly chalk in regular beds, with *Am. varians, Am. rotomagensis, A. Mantelli*, and *Turr. costatus.*

Passing into the Marne, we find from Professor Barrois' account that the above succession is continued to Vitry. The only noteworthy change is that the highest part of the white chalk becomes somewhat clayey, and contains many small Gasteropods and Brachiopods ; at Mont Moret *Turrilites costatus* and *T. tuberculatus* were also found in it. He estimates the total thickness at 70 to 80 feet.

The Cenomanian facies above described is maintained by Vavray and Changy to Possesse and Charmont, but Cephalopoda become rare. Near Charmont another change begins to show itself; the lower grey marl becomes glauconitic, and contains also scattered phosphatic nodules ; moreover, it passes downwards into a dark green argillaceous sand without fossils. This greensand is referred by Professor Barrois to his zone of *Pecten asper*, and is regarded as the continuation of his " Sables de la Hardoye " (to be mentioned presently), but Professor de Lapparent speaks of it as replacing the marly chalk with *Am. varians* (craie ammonitifère).† The total thickness here appears to have diminished to between 50 and 60 feet, and the sand rests directly on the Gaize de l'Argonne, which is the equivalent of our Upper Gault (zone of *Am. rostratus*).

A similar succession is found near Monthois and Vouziers in the Ardennes, and is given by Professor Barrois as follows :—

	ft.
White marl, with *Holaster trecensis, Ostrea canaliculata, Vermicularia umbonata*, etc. - - - - - - -	33
White marl with small grains of glauconite - - - -	10
Glauconitic marl, with black phosphate nodules in the middle	10
Drak green argillaceous sand - - - - - - - -	20
	73

Between Vouziers and Rethel another stratigraphical change takes place, a greyish-white argillaceous marl coming in below the green *Sables de la Hardoye.* This is called the *Marne de Givron* by Professor Barrois, and is referred by him to the zone of *Pecten asper*, while M.M. Peron and de Lapparent consider it as an expansion of the upper part of the Gaize. It rapidly thickens northward till near Givron itself it is about 100 feet thick, the deposit being thickest where the Gaize is thinnest. The fauna of this marl will be discussed in the sequel.

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* Notes pour l'histoire du Terrain de Craie (1887), p. 53.

† Traite de Géologie, fourth edition (1900).

The Marne de Givron forms the hills between Chaumont Porcien, Rocquigny, Draize, and St. Jean du Bois. It passes up into the Sables de la Hardoye without any break, the marl becoming sandy, and this changing to a sand composed of quartz grains and large grains of dark green glauconite. The marl contains a fair number of fossils, but the sands very few ; neither the one nor the other contains phosphatic nodules. The overlying bed of glauconitic marl does contain such nodules, black, and apparently derived, and this bed Prof. Barrois regards as the equivalent of the zone of *Ammonites laticlavius.*

In the north of the Ardennes the "marne de Givron" becomes very thin, and in the Aisne it thins out entirely, allowing the "sables de la Hardoye" to rest directly on the Gaize de Marlemont. All the beds become thinner, and green grains appear even in the white marls (zone of *Bel. plenus*). In the north of the Aisne the succession is as follows :—

		ft.
White marls with green grains, *Bel. plenus*	about	12
Glauconitic marl with phosphate nodules		20
Bright green glauconitic sand.		
		32

Department du Nord.—The succession described as occurring in the north of Aisne (Hirson and Mondrepuits) appears to be continued in the Department du Nord, but on crossing the boundary between these Departments we enter the country where the Cenomanian rests on the Palæozoic rocks, and where all such deposits are locally known as Tourtia. Professor Barrois believes that the "glauconie de la Hardoye" runs on through the arondissement of Avesnes, but he prefers to call it here the "Greensand of Avesnes."

One of the most celebrated localities for Tourtia is that of Sassegnies, about seven miles north-west of Avesnes, and here the Cenomanian basement bed is a yellowish sandy marl with limonite and pebbles and many fossils, its thickness being about 3 feet. Above it is a marly glauconitic sand with fewer fossils, but containing *Pecten asper, Exogyra conica, Ostrea phyllidiana,* and *O. vesiculosa,* all of which occur in the bed below.

Professor Barrois is inclined to regard the lower bed as a representative of the *marne de Givron,* and the higher as the *greensand of Avesnes,* but he expressly says that he has some hesitation in suggesting such a correlation. We would remark that the marne de Givron, having once thinned out against the Palæozoic shore, is not likely to set in again on the south side of the axis of Artois ; hence we think that the two beds at Sassegnies are merely littoral representatives of the central part of the Cenomanien. The fauna they contain is of a generalised shallow water Cenomanian type like that of the Grès du Maine in the west of France, and includes the following species,

Ammonites bochumensis
,, Mantelli
Nautilus subradiatus
Pleurotomaria perspectiva
Cyprina ligeriensis
,, quadrata
Pecten asper
,, orbicularis
Lima simplex
Spondylus striatus
Exogyra conica
,, haliotoidea
Ostrea canaliculata
,, frons
,, phyllidiana
,, vesiculosa
Rhynchonella compressa
,, grasiana
Cidaris vesiculosa
Ditrupa difformis

A little further north is Boussières, where similar beds occur, and are overlain by marl containing *Bel. plenus.* The section in one quarry at this place is as follows:—

	ft.	in.
5. White sandy marl with glauconite grains - - -	13	0
4. Bluish-grey marl - - - - - - - - -	6	6
3. Glauconitic marl with *Bel. plenus* and many sharks' teeth - - - - - - - - - -	1	0
2. Bright green marl with many fossils at the base (see list below) - - - - - - - - -	7	3
1. Thin layer of marl with grains of limonite and glauconite, resting on - - - - - - - -	0	3
Devonian limestone.		
	28	0

The thin layer at the base is analogous to that in the same position at Sassegnies, but as there is no sand above, Professor Barrois considers the "glauconie d'Avesnes" to be absent, and regards No. 2 as the zone of *Ammonites laticlavius,* No. 3 being that of *Bel. plena.* But *Am. laticlavius* does not occur, and we do not think that satisfactory results will ever come from the endeavour to find the zones of Wissant in the thin and variable set of Tourtias.

The Tourtia must be regarded from a more general point of view. That many of its fossils are species which only occur at the base of the Cenomanian in the deeper parts of the Anglo-Parisian basin is only what might be expected, for such species would migrate shorewards as the water became too deep for them. Hence we can see no reason why Nos. 1 and 2 of the above section should not be regarded as a littoral representative of some higher part of the Lower Chalk.

The accompanying diagram (Fig. 53) will assist the reader to comprehend the lithological changes which have been described in the preceding pages.

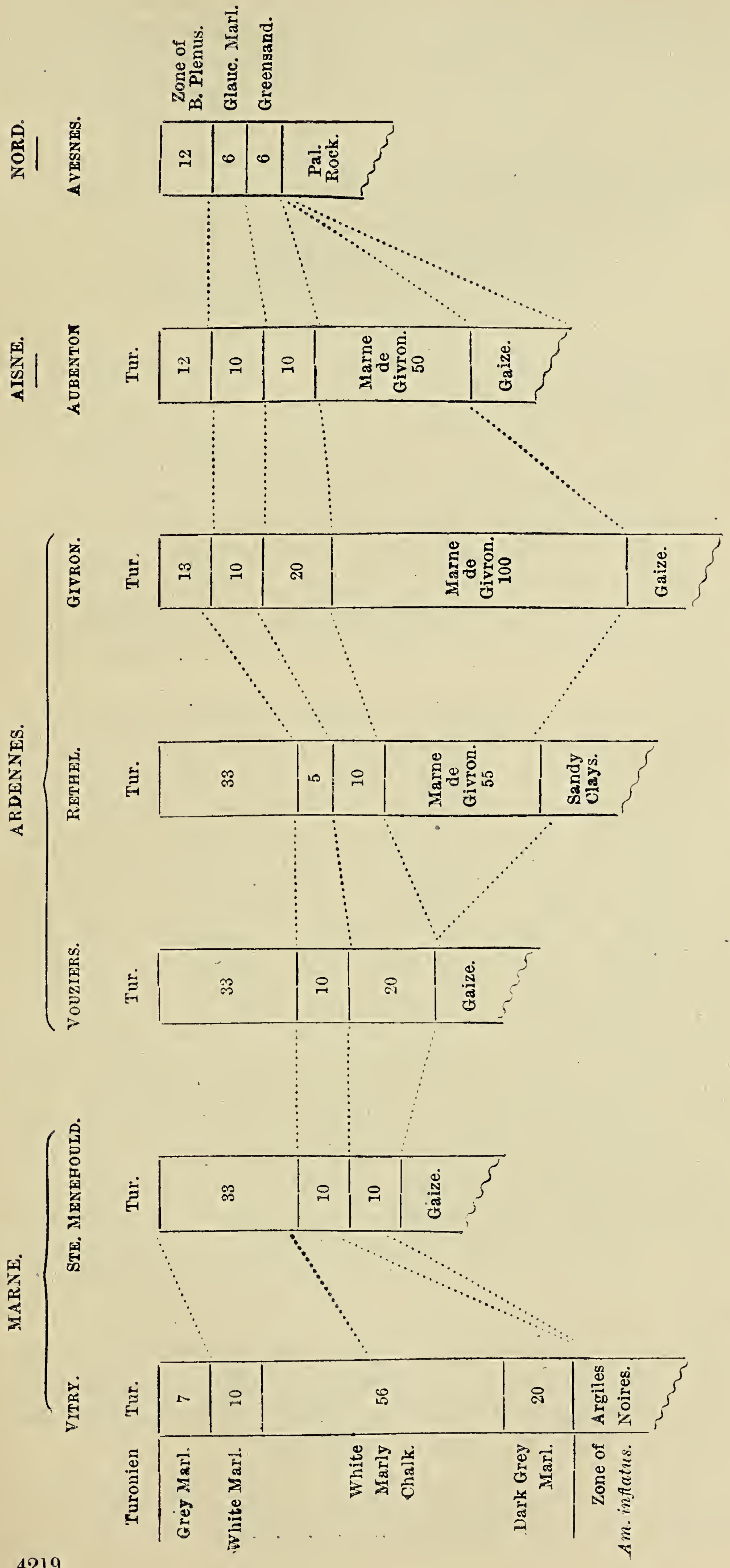

Fig. 53.—Comparative Sections of the Cenomanian in the East of France.

Vertical Scale 60 feet to an Inch.

Critical Remarks.—It will be seen from the preceding account and from that previously given of the Gault and Gaize in Volume I. that the Albian and Cenomanian in the north-east of France form a very complex series of beds, and that it is difficult to assign the several members of the series to their correct zonal horizon.

The general correlation proposed by Professor Barrois in 1878 for the Departments of Aisne and Ardennes was as follows:—

Zone of Bel. plenus.—White and grey marls.
,, ,, Hol. subglobosus.—Wanting
,, ,, Am. laticlavius.—Glauconitic marls.
,, ,, Pecten asper. {Sables de la Hardoye, Marne de Givron.

We must remember that by the zone of *Belemnites plenus* he means an equivalent of some 60 feet of chalk at Wissant and Dover, and not merely the band of marl to which we apply the name in England. His zone of *Holaster subglobosus* includes the Wissant zones of *Am. rotomagensis* and *Am. varians* (116 feet thick); in 1878 he considered this to be absent, but we have reason to think he would not maintain this view now. We strongly dissent from it both on the ground that there is no sign of a break of any kind but a complete passage from glauconitic marl to the whitish marl, and because we doubt the reference of the former to the zone of *Am. laticlavius.*

By the zone of *Am. laticlavius* Professor Barrois means what we have called the subzone of *Stauronema Carteri*, the true Chloritic Marl of Folkestone and the Isle of Wight. Now it does not appear that he found a single specimen of *Ammonites laticlavius* at any locality in the departments of the Ardennes, Aisne, and Nord, and that fossil is not in England confined to the *Stauronema* zone. Further, he only mentions two specimens of *Stauronema*, and these are preserved in black phosphate and may have been derived. We do not think this evidence is sufficient. No doubt Professor Barrois was also influenced by the presence of phosphatic nodules and by the occurrence of *Pecten asper*, but neither of these facts can be allowed to have much weight. This has practically been admitted by Professor Barrois himself, who notes the occurrence of *P. asper* at Bois des Haies in the Ardennes many feet above the bed which he regards as the zone of *Am. laticlavius*, and he appends this note:—"This is not the first time that *Pecten asper* has been recorded from above the greensand with *P. asper*. M. Hébert has recorded it from Vitry-le-François, and I have recognised it at Saully (Yonne) in the zone of *Holaster subglobosus.*"

The opinion of Mr. W. Hill and myself was expressed in 1896,[*] when we showed that the beds containing *P. asper* at Cap la Hève represented the lower part of our Lower Chalk, *i.e.*, of what Professor Barrois calls the zone of *Holaster subglobosus.*

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[*] Delimitation of the Cenomanian, Quart. Journ. Geol. Soc., Vol. lii. p. 170, and Ann. Soc. Geol. Nord., Tom. xxiv. p. 227.

We think it is just the same in the eastern part of France, and that the glauconitic marl which he refers to the zone of *Am. laticlavius* is merely a part of Prof. Barrois' zone of *Hol. subglobosus.* Without personal examination of the sections we are not prepared to say what part.

We come next to the Sables de la Hardoye, and here, again, we are met by a want of evidence. Professor Barrois only collected nine species of fossils in these sands in the whole of its range, and none of these are characteristic or critical species; not one of them is a Cephalopod. It is true that three of them do not in England range above the Upper Greensand; these are *Vermicularia concava, Verm. polygonalis,* and an *Exogyra* like *E. digitata.* But these are forms which would be very likely to survive in places where the local conditions were suitable, after their extinction in the areas of deeper water.

It has been mentioned that Professor de Lapparent considers that the greensand of Ste. Menehould replaces a part of the Chalk Marl of Vitry, and as this greensand is believed by Prof. Barrois to be the continuation of his Sables de la Hardoye, we see no reason why the whole of this sand, as well as the Sable d'Avesnes, should not be regarded as representing a portion of the zone of *Am. varians.*

Finally, we come to the Marne de Givron, which is in some respects the most puzzling deposit of all. According to Prof. Barrois it forms the lower part of his *Pecten asper* zone, and might be compared with the Chert Beds of Wiltshire, while for Professor de Lapparent it replaces the upper part of the Gaize. So far as the stratigraphical evidence is concerned, one or other of these views would certainly seem the most natural interpretation of the facts, but when we examine the fauna of the Marne de Givron, we shall see it cannot belong to the zone of *Ammonites rostratus.* The characteristic fossils of that zone are absent, and the *Ammonites* which do occur are *falcatus, varians,* and *Coupei,* all characteristic of the true Cenomanian. If the fauna were considered apart from any stratigraphical bias, it would undoubtedly suggest correlation with the zone of *Ammonites varians—i.e.,* with the Chalk Marl of England, and with the *craie glauconieuse* of Havre and Rouen. I admit, however, that it can also be compared with that of the Rye Hill sand, (or subzone of *Catopygus columbarius*), and consequently Professor Barrois may be right in placing it below the horizon of *Am. laticlavius.*

The following is a list of the fossils recorded by Dr. Barrois from the three horizons which he denominates (1) Marne de Givron, (2) Sables de la Hardoye, and (3) zone à l'*Ammonites laticlavius;* in the Departments of Aisne, Ardennes, and Marne:—

	1	2	3
Ptychodus polygyrus, *Ag.*	—	—	x
Belemnites ultimus, *d'Orb.*	—	x	—
Nautilus subradiatus, *d'Orb.*	x	—	—
Ammonites falcatus, *Mant.*	x	—	—
,, varians, *Sow.*	x	—	—
,, Coupei, *Brongn.*	x	—	—
Turrilites Bergeri (var. in *Sharpe*)	x	—	—
,, tuberculatus, *Bosc.*	x	—	—
Aporrhais varicosa, *d'Orb.*	x	—	—
Pleurotomaria Guerangeri, *d'Orb.*	x	—	—
,, Dumonti, *d'Arch.*	—	—	x
,, perspectiva, *Mant.*	—	—	x
Turbo Mulleti, *d'Arch.*	x	—	—
,, rotomagensis, *d'Orb.*	—	—	x
Arca carinata, *Sow.*	x	—	—
,, mailleana, *d'Orb.*	—	—	x
,, passyana, *d'Orb.*	—	—	x
Astarte sp.	x	—	—
Cardita sp.	x	—	—
Cyprina quadrata, *d'Orb.*	—	—	x
,, ligeriensis, *d'Orb.*	—	—	x
Exogyra conica, *Sow.*	—	x	x
,, digitata, *Sow.*	—	x	x
,, haliotoidea, *Sow.*	—	—	x
Inoceramus orbicularis (=latus *d'Orb.*)	x	—	—
,, virgatus, *Schlüter* (=striatus, *Sow.*)	x	—	x
Isoarca obesa ? *d'Orb.*	x	—	—
Lima semiornata, *d'Orb.*	—	—	x
,, sp.	x	—	—
Ostrea carinata, *Sow.* (=frons, *Park.*)	—	x	x
,, lateralis, *Nilss* (=canaliculata, *Sow.*)	x	x	x
,, Lesueuri, *d'Orb.*	x	—	x
,, phyllidiana, *Lam.*	—	—	x
,, ricordeana, *d'Orb.*	x	—	x
,, vesiculosa, *Sow.*	—	—	x
Pecten asper, *Lam.*	x	x	x
,, elongatus, *Lam.* (in *d'Orb.*)	x	—	x
,, Galliennei, *d'Orb.*	—	—	x
,, hispidus, *Goldf.*	x	x	x
,, orbicularis, *Sow.*	x	x	x
,, rotomagensis ? *d'Orb.*	—	x	—
,, *cf.* subaratus, *Nilss.*	—	—	x
,, (Neithea) 4-costatus, *Sow.*	—	x	x
,, ,, 5-costatus, *Sow.*	x	—	—
Pinna sp.	x	—	—
Plicatula inflata, *Sow.*	—	—	x
,, sigillina, *Woodw.*	—	—	x
Panopæa Roemeri ? *d'Orb.*	—	—	x
Spondylus latus, *Sow.*	—	—	x
,, striatus, *Sow.*	—	x	x
Trigonia Constanti, *d'Orb.*	—	—	x
,, vicaryana, *Lyc.*	—	—	x
Venus faba, *Sow.*	—	—	x
Kingena lima, *Defr.*	—	—	x

	1	2	3
Rhynchonella compressa, *Lam.*	x	–	–
,, depressa ? *Sow.*	–	x	x
,, grasiana, *d'Orb.*	x	x	x
,, Martini, *Mant.*	x	–	x
,, Schlœnbachi, *Dav.*	–	–	x
Terebratula semiglobosa, *Sow.*	–	–	x
, squamosa, *Mant.*	–	–	x
,, dutempleana *d'Orb.* (=biplicata)	–	–	x
Terebratulina rigida, *Sow.*	x	–	–
,, striata, *Wahl.*	x	–	x
Magas sp.	–	–	–
Pollicipes sp.	x	–	x
Vermicularia concava, *Sow.*	–	x	–
,, polygonalis, *Phil.*	–	x	–
Discoidea subuculus, *Klein*	–	–	x
Pseudodiadema sp.	–	–	x
Micrabacia coronula, *Goldf.*	x	–	–
Onchotrochus Carteri, *Dunc.*	x	–	–
Polycœlia lævigata, *Roemer*	x	–	–
Stauronema (in black phosphate)	–	–	x
Hylospongia (in black phosphate)	–	–	x

Of the species recorded from the Marne de Givron all except five occur in the Lower Chalk or Chloritic Marl of southern England. The five exceptions are *Aporrhais varicosa, Pleurotomaria Guerangeri, Turbo Mulleti, Ostrea ricordeana,* and *Polycœlia lævigata,* and the first four of these are all French Upper Cenomanian species

CHAPTER XXI.

THE LOWER CHALK (CENOMANIAN) IN THE NORTH-WEST OF FRANCE.

General Remarks.

On the western side of the Paris basin the Cenomanian beds, which include the representative of our Lower Chalk crop out in the Departments of the Seine Inférieure, Eure, Eure et Loir, Calvados, Orne, and Sarthe.

In the eastern part of this district the beds consist mainly of chalky marls, more or less glauconitic, but comparable to those of the English Lower Chalk, and these are well exposed near Rouen and Pavilly. When traced toward the west, however, the beds become more glauconitic and more sandy, the sandiness increasing toward the south-west till in the Sarthe there is neither marl nor chalk, but a series of sands and calcareous sandstones.

With regard to thickness the beds comparable with our Lower Chalk are believed to be from 150 to 160 feet thick in the eastern part of the Seine Inférieure, but thin gradually westward along the coast till they are not more than 60 or 70 feet thick in Calvados. Toward the south-west, however, the beds thicken as the arenaceous facies comes on, and expand in the Sarthe to a thickness of about 300 feet.

In the following pages we shall give a brief account of the coast section near Havre, and of the exposures near Rouen, Vimontiers (Orne) and Theligny (Sarthe). For more detailed accounts the reader is referred to a paper by Mr. Hill and myself (Quart. Journ. Geol. Soc. Vol. lii. p. 99), to papers by M. Bizet in the Bull. Soc. Geol. Norm., Vols. viii. and xi., and to the volume by M. Guillier on the Geology of the Sarthe (1886).

Stratigraphical Details.

Seine Inférieure.—The cliffs of Normandy east of Cap la Hève present a fine section of the Cenomanian, which here exhibits a special facies, partly sandy and siliceous and partly chalky, so that it forms a connecting link between the purely chalky facies of the Isle of Wight and the arenaceous deposits of the Orne and Sarthe.

This coast section near Havre has been studied by many French geologists, and notably by Messrs. Hébert and Lennier, but these two observers differed as to the horizon which should be regarded as the base of the Cenomanian, and until 1896 the views which prevailed in France with respect to the correlation of the beds seen near Havre with the Gault Greensand, and Lower Chalk of England were both indefinite and erroneous.

To Mr. W. Hill belongs the credit of ascertaining and proving how much of the so-called Cenomanian of Normandy is really the equivalent of our Lower Chalk. He visited it and other French localities on several occasions during 1895, and his observations were published in a joint paper with myself on "A Delimitation of the Cenomanian."* Mr. Hill satisfied himself that the bed which M. Lennier had regarded as the true base of the Cenomanian was the equivalent of the Chloritic Marl or zone of *Stauronema Carteri* of the Isle of Wight.

This bed (No. 1 in the tabular view, Fig. 54) is separated from the marly sand below by a well-marked plane of division, and has at its base a thin seam of brownish sand. The bed itself consists of grey marl, full of large dark green glauconite grains, and contains many black phosphatic nodules and many fossils, among which Bryozoa and Sponges are abundant. *Stauronema Carteri* is common, and *Am.* [*Acanth.*] *Mantelli, Am.* [*Acanth.*] *navicularis* and *Am.* [*Schloenb.*] *varians* make their first appearance in this bed. At and near Cap la Hève there are indeed two beds of similar character at this horizon with a combined thickness of 6 feet, but as they are followed eastward to St. Jouin, where they come down to the beach, they become condensed into one bed 3½ feet thick. At St. Jouin the full thickness of this Cenomanian group comes into the cliff, and the section there seen is represented in Fig. 54.

The beds numbered 2 to 7 represent the lower part of our Chalk Marl, but differ in containing much more siliceous matter, partly in the form of fine quartz-sand, partly in the abundance of sponge-spicules, and partly as disseminated globular colloid silica. They contain also frequent layers of chert-nodules.

The hard grey bed, which is numbered 8 in the accompanying section much resembles the Totternhoe Stone of Norfolk and Suffolk. It has clearly been formed under similar conditions, but does not form a zonal limit, for most of the fossils which occur below range into the beds above.

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* Quart. Journ. Geol. Soc., Vol. lii. p. 99.

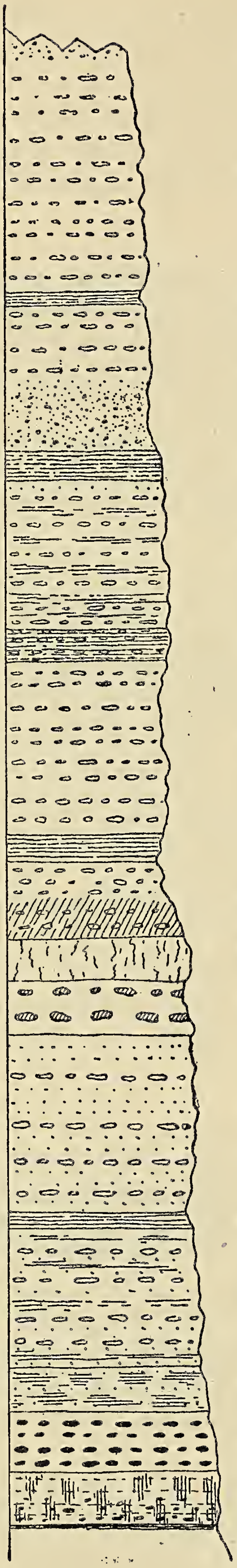

Fig 54.—The Succession at St. Jouin.

Scale 16 feet to an inch.

		ft.	in.
16	Greyish-white chalk, divided into courses by layers of cherts, which are bluish-grey inside - - - -	30	0
15	Grey marly chalk - - - - - - - - -		
14	Grey glauconitic chalk, often rough and gritty, with some black cherts and many brown phosphatic nodules - -	11	0
13	Grey chalk, with hard calcareous lumps - - - - -	2	0
12	Greyish-white chalk, slightly glauconitic, with layers of grey or black cherts - - - - - - - -	11	0
11	Yellowish-grey chalk, with hard calcareous lumps - -	2	6
10	Yellowish-grey glauconitic chalk, with many grey cherts, both scattered and in layers, and also hard calcareous masses - - - - - - - - - - -	12	9
9	Greyish-white shelly chalk, with calcareous lumps; some grey cherts in the middle part - - - - - -	7	6
8	Hard grey chalk, with a layer of green-coated nodules at the top - - - - - - - - -	3	3
7	Grey glauconitic chalk, with two layers of cherts; the lower very large - - - - - - - - -	3	9
6	Yellowish-white, slightly glauconitic chalk, with courses of cherts at intervals - - - - - - - -	13	0
5	Bluish-grey marly chalk - - - - - - -	1	0
4	Buff-coloured chalk, streaked with bluish-grey, with courses of cherts at intervals - - - - - -	10	0
3	Bluish-grey, marly, glauconitic chalk, with hard calcareous lumps - - - - - - - - - - -	3	6
2	Buff-coloured chalk, with four courses of black cherts -	5	0
1	Soft grey glauconitic sandy marl, with many black phosphatic nodules - - - - - - - -	3	
	Grey sandy glauconitic marl (Gaize).		
		120	9

Another remarkable bed is that numbered 14, characterised by the presence of brown phosphatic nodules. This is rich in fossils, and especially in Cephalopoda, all the species so common in our Chalk Marl occurring here, though often as casts and fragments. The following is a list of the species found by Mr. Hill in this bed :—

Nautilus, sp.
Hamites simplex ?
Scaphites æqualis.
Ammonites [Hoplites] falcatus.
,, [Acanth.] Mantelli.
,, [Schloenb.] Coupei.
,, [,,] varians
Turrilites costatus.
,, tuberculatus.
Aporrhais sp.
Avellana cassis.
Exogyra conica.
Ostrea canaliculata
Pecten asper.
Pecten elongatus.
,, puzosianus.
,, (Neithea) æquicostatus.
,, ,, 5-costatus.
Terebratella Menardi.
Rhynchonella dimidiata.
,, convexa.
,, grasiana.
Caratomus rostratus.
Cidaris vesiculosa.
Glyphocyphus radiatus.
Holaster subglobosus.
Discoidea subuculus.
Pseudodiadema ornatum.

Holaster subglobosus sets in with the Ammonites at the base of the formation, but is not common till Bed 12 is reached, and continues common up to Bed 15. The greyish-white chalk above this resembles beds of a similar colour in our Lower Chalk except for the frequent layers of cherty flints. Fossils, however, are scarce in it. In this section there does not seem to be any representative of the marl with *Actinocamax plenus ;* for this whitish chalk is succeeded directly by nodular chalk with *Inoceramus mytiloides.*

I have little doubt that the bed with brown phosphatic nodules (No. 14) corresponds with the well-known fossiliferous horizon of Mont Ste. Catherine, near Rouen, for this horizon is near the top of the Cenomanian. The following particulars of this section are given by Messrs. Lennier and Bucaille,* their measurements in metres being given approximately in feet :—

	ft.	in.
Nodular chalk (=the Melbourn Rock), see p. 496 - -	6	6
Grey or greenish marly chalk, weathering into laminæ ; this is the horizon of *Actinocamax plenus* - - - -	0	8
Layer of nodules formed of hard greyish chalk, greenish on the outside - - - - - - - - - - -	1	4
Sandy micaceous chalk with some glauconite, becoming nearly white when dry, *Holaster subglobosus*, *Am. navicularis* - - - - - - - - - - - -	4	0
Soft grey glauconitic chalk with many small brown nodules	0	8
Fossiliferous bed, formed of glauconitic chalk, hard stone, and yellowish sand, with many Cephalopods and other fossils, *Am. rotomagensis*, *Scaphites æqualis*, etc. - -	1	4
Yellowish-grey glauconitic chalk, with many small concretions of sandy limestone, *Inoc. striatus* (very common) and *Discoidea subuculus* - - - - - -	6	6

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* Bull. Soc. Geol. Norm., Vol. vi. p. 389.

	ft.	in.
Layer of brown chert, continuous	0	1
Yellowish-grey chalk, slightly glauconitic, with many layers and concretions of brown or black chert, seen for a depth of about	40	0
About	60	0

The total thickness at Rouen is believed to be more than 160 feet. The layer of green-coated nodules near the top may indicate the erosion and removal of a certain thickness of the chalk which is shown in the cliff at St. Jouin.

Orne and Sarthe.—Passing now to the departments of the Calvados and Orne, there are sections near Blangy, Lisieux, and Orbiquet which expose the lower part of Cenomanian series, corresponding with Beds 1 to 12 of the section at St. Jouin. The beds seen at these localities consist of yellowish-grey or buff-coloured chalk, more or less glauconitic, with grey cherts and often hard lumps of silicified rock. Mr. Hill found by examination of samples under the microscope that the material is really a siliceous chalk, sometimes containing 50 per cent. of colloid silica with a certain amount of fine quartz-sand.

There are good sections of the whole formation at Vimoutiers in the Orne, and in this district it has been divided by local geologists into two zones, that of *Am.*[*Acanth.*] *rotomagenis* for the upper part, and that of *Am. Mantelli* below. From some fresh observations recently communicated to me by M. Lecœur, of Vimoutiers, and combining the sections seen in several quarries, the complete succession seems to be as follows, the thickness being greater than he formerly supposed:—

		Feet.
Zone of *Am. Rotomagensis.*	Alternating beds of soft grey glauconitic marl and hard yellowish crystalline siliceous limestone, with a bed of the latter at the base. Fossils are numerous, and many are in light brown phosphate	30
	Fine glauconitic sandy chalk, with courses of rough siliceous limestone and occasional lumps of chert	60
	Bed of grey glauconitic sand with many fossils, including teeth and vertebræ of fish	1½
Zone of *Am. Mantelli.*	Greyish marly glauconitic sand, with some rough and harder beds, many cherts occur, both scattered and in layers	28
	Buff-coloured glauconitic and sandy chalk, consisting largely of hard irregular siliceous lumps with soft silty chalk between; also two layers of large cherts and some scattered cherts	22
	A course of large detached masses of sandy glauconitic limestone	1
	Greenish sandy marl, passing down into dark green glauconitic sand	10
	About	152

Followed by Gacé to Mortagne the lower part of the Cenomanian becomes still less chalky, and passes into a yellowish, sandy, micaceous, and glauconitic material which resembles the Gaize de l'Argonne more than any kind of chalk. Layers and scattered masses of chert continue to occur in it at Gacé, but near Mortagne and Bellême they are fewer, and seem to be replaced by beds of siliceous limestone.

The upper zone, or "craie de Rouen," consists of a greyish-white siliceous marl or "tuffeau," rather soft in the quarry, but having the property of hardening in the air, so that it is quarried and used as a building stone. The highest part of this zone consists of beds of silty chalk, alternating with layers of greyish marl, more or less glauconitic, and containing *Scaphites æqualis* and *Baculites baculoides* like those at a similar horizon at Rouen.

These marls are succeeded by the "sables de Perche," soft yellowish sands containing *Ammonites* [*Acanthoceras*] *navicularis, Ostrea carinata,* and *O. columba.*

Still further south, in the department of the Sarthe, another mass of sands is developed in the centre of the formation between the zone of *Am. Mantelli* and the marls with *Scaphites æqualis,* so that the succession established by M. Bizet in the communes of Theligny and Launay is as follows:—

	Feet.
Sables de Perche à *Am. navicularis* - - - - -	+20
Craie à *Scaphites æqualis, Turr. costatus,* etc. - - -	60
Sables et grés à *Perna lanceolata* - - - - -	130
Craie glauconieuse à *Am. Mantelli* - - - - -	80
Glauconie à *Ostrea vesiculosa* - - - - - -	25
	More than 315

Near Le Mans the whole formation has become arenaceous, consisting of sands with beds and masses of calcareous and ferruginous sandstone.

The following is a list of the fossils which have been found in the several portions of the Cenomanian series near Vimoutiers. It has been compiled partly from the specimens obtained by Mr. Hill in 1895, and partly from information and specimens which M. Lecœur has been kind enough to send me. The list of fossils obtained by him from the sand below the zone of *Am. Mantelli* has been given previously in Volume I. of this Memoir, but as so many of them range up into the beds above, it is repeated here for comparison. The last column shows those which are known to occur in the English Lower Chalk:—

	Zone of Turrilites Bergeri.	Zone of Ammonites Mantelli.	Zone of Ammonites Rotomagensis.	English Lower Chalk.
Cephalopoda.				
Ammonites [Hoplites] falcatus, *Mant.*	–	–	x	e
,, [Acanth.] cenomanensis, *d'Arch.*	–	–	x	e
,, [,,] Mantelli, *Sow.*	–	x	–	e
,, [,,] navicularis, *Mant.*	x	x	–	e
,, [,,] rotomagensis, *Brongn.*	–	–	x	e
,, [Schloenb.] Coupei, *Brongn.*	–	–	x	e
,, [,,] varians, *Sow.*	?	–	–	e
Baculites baculoides, *Mant.*	–	–	x	e
Hamites simplex, *d'Orb.*	–	–	x	e
,, ornatus ?	x	–	–	–
Scaphites æqualis, *Sow.*	–	–	x	e
Turrilites Bergeri, *Brongn.* (type)	x	–	–	–
,, costatus, *Lam.*	–	x	x	e
,, tuberculatus, *Bosc.*	–	x	x	e
Belemnites sp.	x	–	–	–
Nautilus elegans, *Sow.*	–	x	–	e
,, fleuriausianus, *d'Orb.*	–	–	x	e
Gasteropoda.				
Avellana cassis, *d'Orb.*	–	–	x	e
Columbellina sp.	–	–	x	e
Fusus Espaillaci ? *d'Orb.*	–	–	x	–
Pleurotomaria perspectiva, *Mant.*	–	–	–	e
,, sp. (casts)	–	x	x	–
Lamellibranchiata.				
Ostrea canaliculata, *Sow.* (=lateralis)	x	x	x	e
,, carinata, *Sow.* (=frons)	x	–	x	e
,, hippopodium, *d'Orb.*	–	x	–	e
,, vesicularis, *Lam.*	x	x	–	e
,, vesiculosa, *Sow.* (var. Baylei)	–	x	x	e
Exogyra columba, *Lam.*	–	x	–	–
,, conica, *Sow.*	–	x	–	e
,, haliotoidea, *Sow.*	–	x	–	e
Pecten asper, *Lam.*	x	x	–	e
,, Espaillaci, *d'Orb.*	–	x	–	–
,, Galliennei, *d'Orb.*	x	–	–	d
,, hispidus, *Goldf.*	–	x	–	d
,, orbicularis, *Sow.*	–	x	–	e
,, puzosianus, *d'Orb.*	–	x	–	d
,, (Neithea) æquicostatus, *d'Orb.*	–	x	x	e
,, ,, quinquecostatus, *Sow.*	–	x	–	e
,, ,, cometa, *d'Orb.*	–	x	–	e
Lima Reichenbachi, *Geinit*	–	x	–	d
,, sarthensis, *Guer.*	–	x	–	–
,, simplex, *d'Orb.*	–	x	–	?
,, semiornata, *d'Orb.*	–	x	–	e
,, intermedia *d Orb.*	–	x	–	–
Inoceramus striatus, *Sow.*	–	x	x	e
,, latus, *d'Orb* non *Mant.*	–	x	–	e
Modiola ligeriensis, *d'Orb.*	–	x	–	d
,, inornata, *d'Orb.*	–	x	–	–
Pinna Galliennei, *d'Orb.*	–	x	–	–
Plicatula sigillina, *Woodw.*	–	x	–	e
Myoconcha cretacea, *d'Orb.*	-	–	x	e

	Zone of Turrilites Bergeri.	Zone of Ammonites Mantelli.	Zone of Ammonites Rotomagensis.	English Lower Chalk.
Arca ligeriensis, *d'Orb.*	—	x	—	—
,, passyana, *d'Orb.*	—	x	—	e
Cardium hillanum, *Sow.*	—	x	—	d
Corbis rotundata, *d'Orb.*	—	—	x	d
Cyprina ligeriensis, *d'Orb.*	—	x	—	d
Lucina coquandiana ? *d'Orb.*	—	x	—	—
Pholadomya mailleana, *d'Orb.*	—	x	—	d
Sanguinolaria ?	—	—	x	—
Spondylus striatus, *Sow.*		x	—	e
Trigonia crenulata, *d'Orb.*	—	x		—
,, spinosa, *d'Orb.* (=vicaryana ?)	—	—	x	e
Venus rotomagensis, *d'Orb.*	—	—	x	e
Brachiopoda.				
Kingena lima, *Defr.*	—	x	—	e
Magas Geinitzi ? *Schloenb.*	—	x	—	d
Rhynchonella dimidiata, *Sow.*	x	x	x	e
,, Schloenbachi, *Dav.*	—	x	x	e
,, grasiana, *d'Orb.*	x	x	—	e
,, lamarckiana, *d'Orb.*	—	—	x	—
Terebratula arcuata, *Roemer*	—	—	x	e
,, biplicata, *Sow.*	—	x	?	e
,, tornacensis, *d'Arch.*	—	—	x	d
Bryozoa.				
Diastopora sp.	—	x	—	d
Entalophora ramosissima, *d'Orb.*	—	x	—	—
Micropora sp.	—	x	—	d
Reptomulticlausa papularis, *d'Orb.*	—	x	—	d
Echinodermata.				
Calliderma latum, *Forbes*	x	—	—	e
Catopygus columbarius, *Lam.*	—	x	x	d
Cidaris vesiculosa, *Goldf.*	x	x	—	d
,, glandifera, *Goldf.*	—	x	—	
Cottaldia Benettiæ, *Koenig*	—	x	x	e
Discoidea subuculus, *Klein*	x	—	x	e
Epiaster crassissimus, *Defr.*	—	x	—	e
Glyphocyphus radiatus, *Hoen.*	—	x	e	e
Hemiaster bufo, *Brong.*	—	x	—	d
Holaster carinatus, *Ag.* (=lævis)	—	x	—	e
,, suborbicularis, *Cott.* non d'Orb.	—	x	—	e
Pseudodiadema ornatum, *Goldf.*	—	x	x	e
,, Michelini, *Ag.*	—	x	x	e
,, variolare, *Ag.*	—	x	x	e
Pentacrinus (joints)	x	—	—	—
Spongida.				
Plocoscyphia sp.	—	x	—	—
Guettardia stellata, *Mich.*	—	x	—	—
Tremacystia d'Orbignyi, *Hinde*	—	x	—	d
Foraminifera.				
Patellina concava, *Lam.*	x	—	x	—

A perusal of the above list will show that almost all the fossils which occur in the Cenomanian zones of *Am. Mantelli* and *Am. rotomagensis* at Vimoutiers, occur also in our Lower Chalk or in the more arenaceous deposits of Devonshire, which are believed to represent the Chalk Marl. A personal examination of most of the species above quoted has resulted in some alterations and corrections of the lists formerly given, and I have no doubt that a more thorough comparison of French Cenomanian species with English fossils would result in the identification of many other fossils which now bear different names.

There are, as might be expected, a few species which seem to be restricted to western France, such as *Hemiaster bufo, Rhynchonella lamarckiana, Trigonia crenulata, Pinna Galliennei,* and *Fusus Espaillaci.* There are also some species which might have been expected to occur but have not yet been recorded from the Orne or Sarthe, such as *Galerites castanea, Holaster subglobosus, Terebratula semiglobosa, Echinocyphus difficilis, Rhynchonella mantelliana,* and *Plicatula inflata.* But it will be seen that the Cephalopods are entirely those of our Lower Chalk.

Remarks on the Correlation of the Cenomanian and the Lower Chalk.

In the preceding pages we have given a brief account of the beds which are regarded by Mr. Hill and myself as the equivalents of the Lower Chalk of England, but it should be stated that this view when published in 1896 was in opposition to that held by French geologists. They had always supposed that a large part of their Cenomanian was represented in England by our Upper Greensand, and as regards the Cenomanian of Havre in particular it was generally supposed that the lower beds in which *Pecten asper* is common were equivalent to those which Professor Barrois had grouped as the zone of *Pecten asper—i.e.,* the Chert Beds of Warminster, Dorset, Devon, and the Isle of Wight.

This supposition, however, was not based on any detailed comparison of the two sets of beds, but seems merely to have arisen from the existence of certain points of similarity between the Cenomanian of Normandy and the upper part of the English Greensand, such as would naturally strike anyone who knew the English Chalk and Greensand only from published descriptions. These points are—

1. The glauconite character of the beds.
2. The occurrence of frequent layers of cherty concretions.
3. The presence of *Pecten asper* and other fossils common in the Warminster Greensand.

The following remarks on these points are taken from our joint paper previously referred to:—

"(1) It is a mistake to suppose that the material of the 'craie glauconieuse' [of Havre] resembles that of our Greensand. The very use of the word 'craie' indicates the difference, and is quite correct in the department of the Seine Inférieure, where the matrix does consist of fine chalky matter. . . . If we examine the Chalk Marl of the Isle of Wight under the microscope we find that it actually is a *craie glauconieuse;* it consists essentially of minute grains of quartz and glauconite and of shell fragments embedded in a fine chalky matrix. The material of the corresponding part of the Cenomanian at Havre has less of the chalky matrix and more of the inorganic constituents, quartz and glauconite" [but is otherwise similar].

"(2) The occurrence of layers and lumps of true chert does undoubtedly create a superficial resemblance between the two sets of strata; but the researches of Dr. Hinde have so completely proved the connection between the formation of cherts and the existence of siliceous sponges, that the occurrence of cherts can only be taken as evidence of the conditions being locally favourable to the growth of such sponges."

It should have been added that siliceous concretions of a character intermediate between cherts and flints occur in the Lower Chalk of England (Wiltshire and Dorset), and that whether a siliceous concretion develops into a chert or a flint seems to depend very largely on the texture of the deposit in which it is formed; those occurring in deposits which are sufficiently coarse or sandy in texture tending to become nodules of clear chalcedonic chert, while those in a material of such fine texture as ordinary chalk are always flints.

"(3) The presence of *Pecten asper* and other fossils, which in England are chiefly found in the Upper Greensand, is the sole argument which requires serious consideration. Let us first of all see what it amounts to when admitted without any qualification. Where does this special fauna exist in England? Certainly not in the Chert Beds either of Wiltshire, Dorset, or the Isle of Wight, which have everywhere a very limited fauna. The fossils of the Warminster Greensand [which is the fauna in question] have mostly been obtained from a bed of bright greensand lying *above* the Chert Beds and passing up into Chloritic Marl [see p. 156].

"It is quite a mistake to suppose that this is a typical Upper Greensand fauna: it is only that of the very highest bed,* so that if two-thirds of the French Cenomanian are to be correlated with the thin bed of greensand near Warminster on the strength of the similarity between the fauna, we must imagine that this thin bed [varying from 5 to 10 feet] has expanded to a thickness of 80 feet or more in France, although the beds both above and below have very greatly diminished in thickness.

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* Since the above was written we have come to the conclusion that the fossiliferous part of the Rye Hill Sand (a thickness of only 2 feet) should be included in the Cenomanian zone of *Am. varians.*

"Our lists, however, show that of the fossils which may be collected from these beds near Havre in a few days' time; quite as many occur in our Chalk Marl as in the Warminster Beds."

We also pointed out in 1896 that it was unsafe to depend on Echinoderms or ground-feeding Molluscs in correlating two different deposits at some distance apart, because the conditions of life may have been different in the two areas. We believe also that the reason why *Pecten asper* and some other members of the Warminster fauna do not occur in the Chalk Marl is simply because the water became too deep for them, and not because they had everywhere ceased to exist.

We have shown that the Cenomanian of Havre was probably formed in greater proximity to land than the Lower Chalk of our southern coasts, and also that in passing from Havre toward the south-west we reach shallow-water sands and sandstones. It is not surprising, therefore, that there should be a certain corresponding change in the fauna. Is it likely that the same assemblage of creatures would inhabit the littoral sandy floors, as well as the intermediate depths where glauconitic marls and sands were being formed, and the comparatively deep water of the chalk-marl area?

"Further, as the period was one of continued subsidence, and as the formation of the Chalk Marl was preceded by that of glauconitic sand in a shallower sea, what is more likely than that the creatures which lived in that shallower sea should gradually migrate to other tracts where the same conditions prevailed, as the area of the sea grew larger and the central portion of it grew deeper?

"The case is quite different with the Cephalopoda, for they could move freely from place to place, and were not directly dependent on depth of water or on the nature of the sea floor. They must therefore be much more trustworthy chronological guides [than echinoderms and bivalve molluscs]; and if we rely upon their guidance in the present case we find that they lead us to the very conclusion which we regard as correct, for the Cephalopoda of the lower part of the Cenomanian of Havre are identical with those of our Chloritic Marl and Chalk Marl, and they do not occur in the Chert Beds of our Upper Greensand.

"To sum up, therefore, our belief is that the Cenomanian deposits of the Seine Inférieur, Calvados, and Orne, above that horizon which we have taken as its base, were originally continuous with our Lower Chalk, but were formed in a shallower part of the sea, nearer to a coast line and in a region more favourable to the growth of siliceous sponges. Hence they consist of a more sandy material, with a larger amount of siliceous matter in the form of sponge-spicules, this latter leading to the frequent development of chert nodules."

CHAPTER XXII.

THE MICROGRAPHIC STRUCTURE OF THE BEDS FORMING THE ZONE OF AM. VARIANS.

By W. Hill.

Introductory Remarks.

In the following pages it is proposed to give some account of the minute structure and contents of the successive zones of the Chalk as revealed by microscopic examination. Though much work has been done in the study of the Microzoa obtained from the Chalk of various localities and at different horizons, it was not till 1893, when Dr. Hume* published his Micro-Mineralogical Researches, that any systematic attempt was made to investigate the zonal distribution of those minute elements which constitute the greater part of the Chalk. In 1897 again, M. Cayeux† published a series of Monographs, in which he deals exhaustively with the lower beds of the Upper Cretaceous series in Belgium and with the zones of the Middle and Upper Chalk in the Paris Basin.

Besides these two works little has been done, and the endeavour is now made to follow up this "fruitful source" of investigation as far as time and circumstances will permit.

Methods.—Most of the details of the methods of these researches have already been given in a previous volume,‡ but it will perhaps be well to recapitulate them, and an explanation is also necessary as to the way in which the quantities of the various ingredients of the Chalk were estimated.

1. *The Examination of Thin Sections.*—While little could be gained by the study of thin sections of the Gault, much information can be obtained from the Chalk by this means. In the course of many years' work an extensive collection of thin sections has been made of specimens taken from all zones in the Chalk obtained from many localities between Devonshire on the west, Dover on the

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* Chemical and Micro-Mineralogical Researches on the Upper Cret. Zones of the South of England, by Dr. W. F. Hume.

† Contribution à l'Étude Micrographique des Terrains Sedimentaires, by M. Cayeux.

‡ Cretaceous Rocks of Britain, Vol. i.; The Gault and Greensand, Mem. Geol. Survey (1900).

east and Speeton on the north. These have been examined zone by zone and county by county, and their leading characters will be described in the following pages. The figures in brackets which follow certain detailed descriptions of the micro-sections have reference to those specimens which have been subject to further critical examination. (See the tables of analyses.)

2. *The Preparation and Examination of Chemical Residues.*—In order to obtain an idea of the micro-mineralogical contents of the Chalk from various horizons it is necessary to get rid of the chalky matter. For this purpose a series of specimens from each zone was taken, chiefly from localities in Devon, Dorset, Isle of Wight, Kent, Buckinghamshire, Hertfordshire, Cambridgeshire, Norfolk, Lincolnshire, and Yorkshire, and from a few intermediate points.

Portions of the specimens selected were treated by the method employed by Dr. Hume.* The chalk was broken into fragments not larger than a good-sized pea, and dried at a temperature of not less than 100° C. for at least two and a half hours. A portion was then weighed, the quantity taken depending on the size of the specimen. This dried chalk was then treated with a 20 per cent. solution of hydrochloric acid (1·60 sp. gr. B.P.), the resulting solution (with the suspended insoluble matter) being poured off from time to time. After complete solution the whole was allowed to settle in a large beaker, and the clear fluid after passing through a filter was thrown away. Hot water was added to the remainder, and after twenty had been slowly counted, about half the fluid with such material as remained suspended was poured into a second beaker. This process was repeated until the coarser particles were as far as possible separated from the finer. To remove the calcium chloride the whole of the residue was washed with hot water, and the fluid poured off through a filter until there was little or no reaction with a solution of nitrate of silver in the filtrate. Both the finer and coarser residues were dried and weighed separately, and from these weighings the percentages are calculated.

The coarse residue, when the quantity was sufficiently large, was further subdivided by sifting through three sieves of 40, 60, and 90 meshes to the inch. This created four divisions with particles of comparatively relative size; each division was weighed separately. The proportions of the various constituents in each division were then estimated by the eye, a little of the material being spread thinly on a slide and viewed under the microscope, the percentage being calculated in relation to the weight.

From 10 to 100 of the mineral grains in each of the four divisions were measured in their longest diameter, and the average taken. Where the amount of sand was considerable the average size of the grains was calculated in relation to the weight of the respective divisions.

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* Chemical and Micro-Mineralogical Researches, p. 11.

The results obtained by this method of investigation will be found in the tables appended to the description of each zone. The arrangement is as follows:—(1) Each specimen is numbered and its locality indicated. (2) The amount of the material taken follows, and then (3) the percentage soluble in the acid. Then follows (4) the percentage of the coarse, and (5) of the fine residue, and (6) the total quantity of each, with (7) its colour.

The composition of the coarse residue is then given with (1) the names of such detrital minerals as have been recognised, their percentage and the maximum and average size of the grains. (2) The secondary minerals follow, but dimensions of the glauconitic grains only are given; then come (3) the generic names of such Foraminifera as were isolated in the acid residues, and their percentage; the final column (4) being given to shell fragments and particles whose identity is uncertain. Finally, remarks in each case draw attention to any peculiarity seen in the residue; and in brackets are given the leading characteristics of the specimen when seen as a thin section, with the estimated percentage of the recognisable organic ingredients.

The zonal divisions followed are those described in the earlier pages of this volume. It is very necessary in considering the chemical and micro-mineralogical characters of the various zones to indicate as nearly as possible the horizon from whence the specimen comes. It will be seen in the sequel that there are very considerable lateral as well as vertical differences, and the approximate distance in feet above or below some well-marked bed should always be given if possible.

3. *Washings.*—Many specimens of the softer chalks were washed in water without acid, the finer part removed by levigation, and the chief characters of the coarse particles which remained behind noted. These included Foraminifera, valves of Ostracods, fragments of shell, spines of Echinoderms, &c. These particulars are given under the head of "Washings."

Dr. Hume has very kindly put into our hands the results of some further investigations of chalks from Devonshire and the Midlands, which he has had no opportunity to complete. These we have incorporated, but have kept his work separate as far as practicable.

We have also drawn freely from Dr. Hume's published account of the micro-mineralogical aspect of the Chalk. Our best thanks are due to him for giving us all the information in his power of the way in which he has carried on this work.

Mr. J. J. H. Teall, kindly undertook to examine our residues, and to report on the detrital minerals, and Mr. F. Chapman to name the Foraminifera isolated in the residues and washings. To both these gentlemen our best thanks are also due.

In dealing with the different parts of the Lower Chalk we shall describe them in the following order:—

A. Chloritic Marl (base of the *Am. varians* zone).
B. The quartziferous Limestones of Devon.
C. The Marls and Chalks of the *Am. varians* zone.
D. The Totternhoe Stone.
E. Chalk above the Totternhoe Stone.
F. The Belemnite Marls.

Of these subdivisions, the first two will be dealt with in this chapter.

A. The Chloritic Marl and Basement Beds.

Macroscopic Aspect.

In this division is included not only the Chloritic Marl (zone of *Stauronema Carteri*) but also other beds at the base of the Chalk which may not lie on exactly the same palæontological horizon, but which from their glauconitic and sandy nature bear a strong lithological resemblance to it.

The specimens are from the following localities from west to east:—Bookham Farm, North Dorset (the basement bed, but probably not exactly the same horizon as the Chloritic Marl of the Isle of Wight); Lulworth and Mupe Bay in South Dorset; Maiden Bradley, near Warminster, Wilts; Ventnor, Isle of Wight (Ammonite Bed); Folkestone (Greensand); Cambridge Greensand from Arlesey; and a bed of micaceous marl lying at the base of the Chalk at Shouldham, Norfolk.

There is a considerable diversity in the aspect of the specimens. In colour they range from pale grey, Bookham and Shouldham; to a darker grey at Maiden Bradley; grey, sometimes with greenish tint, Isle of Wight; and a decided grey-green at Folkestone.

The Bookham and Lulworth specimens appear to be chalky marls plentifully speckled with glauconitic grains; the highest part of the glauconitic marl of Mupe Bay is similar, but passes down into a green compact sandy rock; that from Maiden Bradley a very sandy, rather hard grey, but somewhat friable stone; that from the Isle of Wight a compact glauconitic rock. The Folkestone sample is a crumbling glauconitic marl, and that from Shouldham a compact marly chalk.

Microscopic Aspect of Thin Sections.

Viewed in thin sections under the microscope with an objective of two-thirds of an inch focus, the aspect of these specimens varies as their external appearance would indicate. That from Bookham (1)* is seen to consist largely of fine amorphous calcareous material, with which are intermingled the glauconitic and mineral grains with a few shell fragments; Foraminifera occur, but take up a very small area in the section, while calcareous "spheres"* are very abundant, and occupy, at least one-third of it. No satisfactory section could be made of the specimen from Maiden Bradley.

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* The numbers in the text refer to the analyses of the specimens in the tables on pp. 271 to 324.

The basement-bed at Lulworth (3a) also consists largely of amorphous material with many "spheres"; the rock is also full of small pieces of shell and a few larger fragments; several of the latter are evidently derived from the plates of an Echinoderm. A few Foraminifera and grains of quartz and of glauconite are scattered through the rock.

In a specimen from the top of the glauconitic marl of Mupe Bay (3b), sand grains are an important feature of the deposit, and glauconitic grains are also numerous. The proportion of coarse shell fragments is also large: many of these are long and thin and give no clue to their derivation, others are *Inoceramus*-prisms and not a few are derived from Echinoderms. Large Foraminifera, chiefly *Textularia*, are common. These coarse materials are irregularly scattered through the amorphous matrix, many of the longer shell fragments have their long axes in the same plane, and the aspect of the whole section suggests current action.

The Chloritic Marl of Ventnor (4) has a similar calcareous matrix; the mineral grains are hardly so prominent as in the Bookham example, but glauconite is more abundant. Large, coarse shell fragments, chiefly *Inoceramus*-prisms and Foraminifera, occupy half the area of the section, but "spheres" are very scarce.

The Folkestone (5) specimen is a glauconitic sand, the interspaces between the grains being now filled with finely granular crystalline calcite, once probably a calcareous mud. Certain areas of small size—seen in a hand specimen as whitish marks or pipings—are filled with fine amorphous calcareous material to the exclusion of the larger glauconitic grains. In such areas "spheres" can be seen, and Foraminifera can be detected in other parts of the slide lying between the grains of glauconite.

The aspect of a thin section of the Cambridge Greensand (6) viewed under the microscope with a 1-inch objective, is that of an evenly-grained, sandy, and rather calcareous mud, containing large grains of glauconite.

The ground mass appears as brownish-grey amorphous matter, largely inorganic, but under crossed Nicols it can be seen to contain calcitic particles, and through this are thickly scattered minute mineral grains; Foraminifera occur here and there and it is possible to pick out occasionally a fragment of a tooth or bone, probably fish remains. Few shell-fragments can be seen. The grains of glauconite are nearly all of large size and though generally distributed through the mass occur also thickly packed in streaks or veins, the interstices being filled up with the amorphous matter and the minute sand grains.

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* For a description of these spheres see under Middle Chalk, p. 500.

In the basement bed at Shouldham (7) glauconitic and mineral grains, with shell fragments, all of small size, are distributed with evenness and regularity through the amorphous calcareous matrix. Foraminifera are present, and the tests of arenaceous forms can be recognised, and, though not a predominating feature, the even character of the marl throws them into greater prominence than usual; "spheres" are comparatively rare.

Examination of the Washings.

Shell Fragments.—In the West of England, at Bookham and Maiden Bradley, these were not abundant;* they were chiefly flat fragments of *Ostrea*, *Pecten*, and *Plicatula*, with a few pieces of *Inoceramus*-shell or detached prisms. At Ventnor these prisms were very numerous; at Folkestone and in the Cambridge Greensand all shell fragments were comparatively rare, while at Shouldham they consisted chiefly of the remains of a small Brachiopod, the largest pieces being those of the stoutest part of the shell around the umbo.

Fragments, apparently those of a minute Belemnite, occurred at Maiden Bradley.

Spines of echinoderms occur in all except the Folkestone specimen; they are of minute size, and may be referred to *Hemiaster* or *Pseudodiadema.*

Minute fish-teeth, coprolites and scales occurred in all of them, but were most numerous in the Shouldham deposit. Here, though not forming a very large proportion of the rock, they were more conspicuous than usual amongst the coarser material.

Sponge spicules and *Hexactinellid* sponge-mesh occurred in all specimens. *Tetractinellid* and *Monactinellid* spicules were also observed, the former rarely, but in the Shouldham marl were several trifid spicules, the siliceous walls of which were entirely replaced by limonite.

Foraminifera.—Foraminifera are by far the most abundant group of Microzoa. The number of species which it was possible to isolate depended much on the comparative hardness of the rock-specimens dealt with. It must also be understood that no attempt was made to discover every species which occurs in each zone; only those were taken which came readily and quickly to hand. It is believed that the chief and the most abundant forms occurring in each zone have been included, with such of the rarer kinds which came under notice from time to time.

The Foraminifera isolated from the washings and residues (excluding the Cambridge Greensand) were named by Mr. Chapman; thirty-seven species and varieties are distributed as follows according to the classification of Dr. Brady:—

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* The specimens from Lulworth and Mupe Bay proved too hard to break up for satisfactory examination.

Family.	Genera.	No. of Species.
Lituolidæ	Reophax	Fragments only
	Haplophragmium	3
Textulariidæ	Textularia	3
	Verneuilina	1
	Tritaxia	2
	Spiroplecta	1
	Gaudryina	3
	Bulimina	7
	Pleurostomella	1
Lagenidæ	Nodosaria	2
	Marginulina	1
	Vaginulina	2
	Cristellaria	4
Globigerinidæ	Globigerina	2
Rotaliidæ	Truncatulina	1
	Anomalina	2
	Rotalia	2

As may be expected, there is considerable difference in the appearance of the arenaceous forms, those of Maiden Bradley and Ventnor having their tests built of very coarse sand grains, whilst those of Shouldham are far more delicately constructed. Fragments of *Reophax* were common in the more sandy specimens of Maiden Bradley and Ventnor. *Haplophragmium* occurred both at Maiden Bradley and Shouldham, and probably is to be found in all localities under consideration. *Tritaxia tricarinata,* and *Trit. pyramidata,* and the Bulimines occurred in all localities. Of the latter *Bulimina Presli* and *Bulimina brevis* were most abundant. Amongst Textularians were *Textularia trochus, T. turris,* and *T. minuta,* and these with *Gaudryina pupoides* complete the list of the commoner arenaceous forms.

Of the others *Anomalina ammonoides, Cristellaria rotulata, Rotalia Soldani,* and *Globigerina cretacea* were the most prominent. The tests of the latter species were all very small. *Spiroplecta anceps,* a common form at Maiden Bradley and Bookham, does not occur in the more eastern samples. Individual specimens were least numerous in the sandy rock of Maiden Bradley and in the Chloritic Marl of Folkestone.

In the Cambridge Greensand Professor W. J. Sollas found forms of *Lituola, Lagena* and *Vitriwebbina* very abundant,* genera which appear to be rare elsewhere. He also notes that *Nodosaria Vaginulina, Frondicularia, Flabellina* and *Bulimina* are common arenaceous forms. In 1899 Mr. F. Chapman published a complete account of the Foraminifera from the Cambridge Greensand enumerating 138 species and varieties belonging to 29 genera.† He observes that many of them, "especially among the larger species, show a marked abrasion of their tests," and he is "strongly inclined to believe that a large proportion of the microzoic fauna has been derived from the upper beds of the

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* See Quart. Journ. Geol. Soc., Vol. xxviii. p. 398 (1872).

† Ann. Mag. Nat. His., Ser. 7., Vol. iii. pp. 48 and 302.

Gault. . . . The facies from this bed is remarkably like that of the Greensand seam in the Gault (zone xii.) at Folkestone."

Ostracoda.—Valves of Ostracods were found in the samples from Bookham, Maiden Bradley and Ventnor, but were not common in any of them, They appear to be more numerous in the Cambridge Greensand, and Mr. Chapman has recorded 45 species from that deposit.* The commonest are species of *Cytherella, Cytheropteron* and *Cythereis.*

Examination of the Residues.

The Detrital Minerals.—These are coarsest at Maiden Bradley, where the largest grains measured 3 mm. and more in their longest diameter, the average size being ·47 mm. in the higher example of the Chloritic Marl in this locality.

They diminish in size as well as in number both to the south-east and to the north-east, their average longest diameter in the Isle of Wight being ·12 mm., Folkestone ·10 mm., Shouldham ·055mm.

Mr. Teall has kindly furnished the following notes on the detrital minerals which occurred in these residues after treatment of the specimens of the Basement beds with acid solution:—

In addition to glauconite, more or less oxidised pyrite or marcasite, and the remains of arenaceous Foraminifera, these residues contain variable amounts of foreign clastic material.

Apart from variations in the size of the grains, and the total amount, this material does not show any marked variation when the samples from different localities are compared. It may therefore be described in general terms.

Quartz is by far the most abundant mineral. The grains are often colourless, but they are not unfrequently tinged with brownish or greenish tints. They contain the inclusions so common in the quartz of granitic and gneissose rocks. Felspar and white mica are also present, but only in very small quantities. Microcline has been observed in one or two cases, and oligoclose is probably also present, although it has not been definitely determined. When the residues are placed in a diffusion column of cadmium ferrotungstate the felspars float either with or above the quartz. Basic felspars are absent.

All the fine-grained residues contain a considerable assortment of heavy minerals. Garnet, staurolite, zircon, rutile, ilmenite, and magnetite were observed in the deposits from Cerne Abbas, Ventnor, and Shouldham. Tourmaline was also recognised in the deposits from each of the above-mentioned localities, except that from Ventnor, and if a larger amount of material had been available it would probably have been found there also.

It follows from the facts mentioned above that the foreign clastic material has been derived from the disintegration of plutonic and metamorphic rocks. No minerals characteristic of volcanic rocks have been observed. (J.J.H.T.)

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* Ann. Mag. Nat. Hist., Ser. 7. Vol. ii. p. 331 (1898).

It cannot, of course, be assumed that the minerals have been derived directly from the parent rocks. They may have done duty, so to speak, in pre-existing sedimentary deposits.

The material obtained from the Cambridge Greensand received special attention with the following results :—

As far as practicable all phosphatic nodules were removed before drying and weighing, though a few minute ones were discovered after treatment with the acid.

The remarkable features of this residue are the smallness of the mineral grains and the abundance amongst them of mica flakes ; some of these were white, silvery, and clear white, others have a dark sooty appearance. Except the mica flakes, which have considerable superficial area, no mineral grain measured exceeded ·16 mm. All the quartz-grains are angular and appear little worn.

The grains of glauconite as a whole are rough and mammillated, and vary in colour from a pale to a dark greyish-green ; all have a dull weathered or worn exterior though from their aspect in thin sections this does not appear to be due to incipient decomposition, for their edges are sharp and clear and there is no suggestion of alteration of their material. Though no grain of exceptional size was noted, the greater part of them are certainly larger than usual. The coarse residue was nearly free from particles of iron oxide.

Secondary Minerals.—Glauconite.—This mineral is more abundant in the Chloritic Marl and basement-beds of the Chalk than at any other horizon. In the Chloritic Marl of Folkestone it is estimated to form 60 per cent. of the material examined, and the proportion in the Cambridge Greensand is probably about the same; at Ventnor there is only 12 per cent. ; at Lulworth and Mupe Bay 13 and 15 per cent. respectively ; Maiden Bradley 9 per cent. ; and at Shouldham about 3·5 per cent. The quantity of glauconite in the first-named specimen agrees fairly well with the typical glauconitic sands of the Challenger collection, which however, "contain 40 to 50 per cent. of Foraminifera and other carbonate of lime shells, together with the remains of siliceous organisms."* Foraminifera are not so important a feature in the Folkestone deposit. Arenaceous Foraminifera are estimated at only 2 per cent. of the coarse residue of this specimen and other forms are by no means numerous.

At Folkestone and Ventnor, in the Cambridge Greensand, and in examples of the Chloritic Marl in the West of England the grains resemble those of the Gault in their rough, furrowed, mammillated outline, but a larger proportion can be recognised as Foraminiferal casts. Writing of the Cambridge Greensand in 1872, Professor Sollas says :† "the glauconitic grains are the casts of Foraminifera, possibly also of other minute shells. The larger casts, about

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* Deep-Sea Deposits. Report of the "Challenger" Expedition, p. 379.
† See Quart. Journ. Geol. Soc., Vol. xxviii. p. 397.

1-40 to 1-60 in. diameter and less, are marked into projecting lobes by deep sulcations, generally lined at the bottom with white calcareous matter, which serves to mark out the limits of each lobe. These forms are derived from *Textularia, Lituola* and *Bulimina;* in size they correspond very closely with such a derivation; just passing through the meshes of a sieve which retain almost all the numerous *Buliminœ* mingled with them. Each lobation of the cast corresponds to the interior of a chamber of the Foraminifer, and each white calcareous line between the lobes is the edge of the septum which once separated adjoining chambers, and now in some cases extends inwards between their casts. This is shown by sections made in various directions through the green grains. . . . Sometimes *Bulimina* are met with having part of their shell worn away, revealing a green cast within." Besides the above he noted grains derived from casts of *Orthocerina, Rotalia, Globigerina Nodosaria* and *Lagena.*

In the basal bed at Shouldham, a finer and more chalk-like deposit, the grains are smoother and rounder, a large number of them being well-formed casts of Foraminifera.

In colour the grains vary from dark green, almost black, to a pale yellowish-grey, and frequently the grains have a thin, pale-green rind of dusty appearance as though they were weathered. Professor Sollas remarks that the grains in the Cambridge Greensand, when slices are viewed with polarised light, show distinct colours, dark green with parallel prisms, and bright lighter-coloured green with crossed prisms.

The largest grains occur in the Chloritic Marl of Folkestone, they average ·31 mm., and this is closely approached in specimens from the West of England. Though the largest grain measured occurred in the glauconitic marl of Mupe Bay, and was ·81 mm. in longest diameter, probably grains of equal size could be found in the basement-beds of other localities.

Marcasite and Ferruginous Matter.—No nodules of bright brassy Marcasite occurred in our specimens of the Chloritic Marl, but possibly the brown porous masses of iron oxide which were found in several specimens have resulted from the alteration of this mineral. At Shouldham were many sponge spicules coated with Limonite. The amorphous matrix will be dealt with under the head of Chalk Marl.

Tabulation of Results.

The following table gives the results of the analysis of nine specimens of the basement beds of the chalk in a tabular form. The methods by of which these results have been arrived at and the explanation of the various columns have already been given on page 262 at the commencement of this chapter. The specimens in this and all following tables are taken from West to East:—

THE CHLORITIC MARL AND BASEMENT BEDS OF THE CHALK.

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per. cent. Coarse Residue.	Per cent. Fine Residue.	Total per cent. Residue.	Colour of Residue.	Detrital Minerals in the Coarse Residue.	Per cent.	Maximum size.	Average size	Secondary Minerals.	Per cent.	Maximum size.	Average size.	Arenaceous Foraminifera.	Per cent.	Indeterminable, etc.	
1.	North Dorset. Bookham Farm, near Cerne Abbas	gr'ms 41·271	76·33	7·86	15·81	23·67	pale grey	Quartz, felspar, rutile, zircon, tourmaline, staurolite, mica, ilmenite garnet, magnetite	33·40	mm 1·00	mm ·21	Glauconite	45·60	mm ·72	mm ·29	Tritaxia, Spiroplecta, Bulimina, Gaudryina	20·57		Hexactinellid spicules not uncommon. (Spheres numerous, Ostracoda scarce, Shell-fragments small not abundant, chiefly of *Pecten, Ostrea*, and *Plicatula* these with foraminifera estimated to form 45 per cent. of the rock.
2a.	Maiden Bradley. Base	36·144	38·47	50·76	10·47	61·53	pale grey	The same	72·43	3·0	·32	Glauconite	19 63	·68	·29	Tritaxia, Textularia, Spiroplecta, Haplophragmium, Verneuilina, Reophax, Bulimina, Gaudryina	7·54	·28	Hexactinellid sponge mesh common, Tetractinellid and Monactinellid sponge spicules also occur. Several silicified shell fragments were found in the residue. The percentage of Foraminifera is not large, but the list includes a greater number than usual of genera and species. (Spheres rare, *Ostracoda* scarce, Shell - fragments same as above.)
2b.	Top	38·279	45·83	43·29	10·88	54·17	pale grey	The same	81·30	3·1	·47	Glauconite	10·68	·63	·28		7·99		
3a.	South Dorset. Lulworth.	76·464	83·65	3·02	13·33	16·35	dark grey	Probably all the minerals recorded above	31·38	1·8	·36	Glauconite	44·81	·60	·28	Reophax, Textularia, Spiroplecta, Bulimina, Gaudryina	21·59	1·0	There were many casts of Foraminifera in glauconite and also rod-like lengths, probably casts of spicular canals. Hexactinellid sponge-mesh was also common. (Recognisable organic *debris*, shell-fragments, Foraminifera, "spheres" &c., form about 40 per cent. of this rock.)
3b.	Mupe Pay. (the top.)	79·444	69·03	16·06	14·91	30·97	dark grey	Same as above	—	—	—		—	—	—				Coarse fragments of various organisms are prominent features in a section of this rock and form about 40 per cent. of the whole deposit, but mineral grains and glauconite also occupy a considerable area in the section.
3c.	Mupe Bay. (5ft. below the top.)	77·314	51·33	42·11	6·56	48·67	dark grey	Same as above	58·37	Up to size of a pea		Glauconite	34·51	·81	·28	Textularia, Bulimina, Gaudryina	4·65		Foraminifera less numerous than at Lulworth. No fragment of *Reophax* noticed. No measurement given of the quartz grains, for small pebbles as large as a pea are common in the lower part.

THE CHLORITIC MARL AND BASEMENT BEDS OF THE CHALK.—*continued.*

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. Coarse Residue.	Per cent. Fine Residue.	Total per cent. Residue.	Colour of Residue.	Detrital Minerals in the Coarse Residue.	Per cent.	Maximum size.	Average size.	Secondary Minerals.	Per cent.	Maximum size.	Average size.	Arenaceous Foraminifera.	Per cent.	Indeterminable, etc.	
		gr'ms								mm	mm			mm	mm				
4.	Isle of Wight. Ventnor	46·094	52·61	27·48	19·91	47·39	dark grey	The same, except tourmaline	42·52	·80	·12	Glauconite	44·21	·60	·23	Reophax, Textularia, Tritaxia, Bulimina, Gaudryina	12·39	·87	Hexactinellid spicules occur both as casts in glauconite and with the silica of the spicular wall still in the colloid state. Minute resinous globules occurred, and a few silicified prisms of *Inoceramus* - shell. Spheres rare, *Ostracoda* not numerous. (Shell-fragments chiefly prisms of Inoceramus, a few fragments of Echinoderms, foraminifera, sponge spicules rare, the whole estimated at 30 per cent. of the rock.)
5.	Kent. Folkestone, near the base of the Chloritic Marl	39·152	25·83	65·95	8·22	74·17	grey -	The same - -	2·0	·90	·10	Glauconite, brown porous, iron oxide	94·0 1·50	·60	·31	Tritaxia, Bulimina	2·	·50	Although here and there large grains of quartz occurred the greater part of the detrital mineral grains rarely exceeded 1 mm. Scarcely any sponge-spicules were noted, but rod-like lengths of glauconite, probably casts of spicular canals, were common. (Shell-fragments not abundant, spheres scarce.)
6.	Cambridge. Greensand Arlsey	77·777	26·67	31·79	41·54	73·33	Brownish grey	Quartz, Mica (black and white) Zircon, Rutile ? Tourmaline.	34·30	·16	·08	Glauconite	58·24	·61	·32	Reophax. Haplophragmium, Lituola, Textularia, Gaudryina, Bulimina Phosphates, Indeterminable .	4·0	1·33 1·66	Comparatively few arenaceous Foraminifera. The greater part of the residue was glauconite, a few rods, probably residuary sponge-spicules, occurred. The mineral grains are all very small. Mica abundant and must form an appreciable percentage of the detrital material
6.	Norfolk. Shouldham	39·772	57·21	14·73	28·06	44·79	grey -	The same, though mica flakes were more abundant.	48·98	·41	·05	Glauconite, brown porous, iron oxide	24·92 2·	·30	·09	Haplophragmium, Tritaxia, Bulimina	20·65	2·90	The glauconite of this residue is in small round grains, less rough. Hexactinellid sponge-mesh and trifid spicules, the walls of both replaced by limonite, occurred. (Spheres present, not abundant. Many fish teeth, scales, and coprolite. Shell - fragments chiefly those of a small *Rhynchonella*. The recognisable organic particles do not exceed 20 per cent.)

Summary of Chemical Results.

It is believed that the treatment by a weak solution of hydrochloric acid (20 per cent.) removes little but the carbonates of lime and magnesia contained in the specimens examined; therefore the first column of the foregoing table, which gives the percentage soluble in acid, represents fairly well the amount of lime plus the small quantity of magnesia which chemical analysis shows to occur in many chalks.

It will be seen by reference to the table that the smallest proportion of fine mud is found in examples from South Wilts and Dorset, where it does not exceed 16 per cent. Eastward it increases to nearly 20 per cent. in the Isle of Wight, and north-eastward to 41 per cent. in Hertford, 28 per cent. in Norfolk. The Chloritic Marl of Folkestone, however, contains only about 8 per cent. of fine inorganic matter.

Further examination shows considerable differences in the coarse residues. Thus in the Folkestone specimen no less than 65·95 per cent. consisted of coarse particles readily separated by levigation (the coarse residue), while those from Maiden Bradley contained 50·79 per cent. and 43·29 per cent. respectively of coarse ingredients, and the lower part of the bed at Mupe Bay yielded 42·11 per cent. of such constituents. At Cerne there was only 7·86 per cent. and in the upper part of the mass at Mupe Bay only 3·02 of coarse material.

There is, however, a great difference in the constitution of these coarse residues, for while glauconitic grains formed 94 per cent. of that from Folkestone, the two from Maiden Bradley contained only 19·63 per cent. and 10·68 per cent. respectively. The Maiden Bradley, examples, however, far exceed that of Folkestone in the amount of sand-grains they contain, the detrital minerals being estimated to form 72·43 per cent. and 81·30 per cent., but in the Folkestone sample the amount of the detrital minerals is only 2 per cent. of the coarse residue. These details are still more striking when the proportions are calculated in relation to the mass of the rock; it will be found then that the sand-grains form 37 per cent. of the sample from the top of the rock at Maiden Bradley 24½ per cent. in the lower sample from Mupe Bay, 11½ per cent. in the Isle of Wight, 7 per cent. at Shouldham, 2½ per cent. at Cerne, and only 1¼ per cent. at Folkestone. It is remarkable that the amount should be so small at Cerne, for Mr. Teall has identified in this rock all the minerals found at Maiden Bradley.

The proportions of glauconite calculated in the same way are 61 per cent. at Folkestone, 14½ per cent. at Mupe Bay, 12 per cent. at Ventnor (base of Bed 5), 9 per cent. at Maiden Bradley, and 3 per cent. at Shouldham.

B. The Quartziferous Limestones of Devonshire.

These beds are of abnormal character, and some of their macroscopic features have been described on p. 130. The lowest part of the deposit is generally very coarse-grained, many of the quartz-grains being as large as a pea. Above this is a hard calcareous sandstone (Bed 11 of Mr. Meyer), consisting chiefly of shell-fragments and quartz-sand compacted by calcite into a hard rock. Still higher is a hard white limestone through which large quartz-grains are plentifully scattered; this is No. 12 of Meyer and B. of our sections. No. 13 (our bed C) is a sandy glauconite chalk, [For microscopic structure, see p. 299.]

1.—*Hard Limestone overlying Greensand west of Beer Harbour.*

69·95 grammes of this material, after treatment with 20 per cent. HCl., yielded; 4·97 grs. = 7·116 per cent.;
Fine residue, 1·25 grs. = 1·78 per cent.;
Heavy residue, 3·73 grs. = 5·33 per cent.;
Thus: $CaCO^3 = 92·88$ per cent.

1. Of the heavy residue that above 1 mm. in diameter weighs 1·09 grs. A noticeable feature in it is the extent of the silicification and the abundance of the detrital materials. The silicified fragments consist of—

(*a*) Brachiopod fragments. One *Kingena* had been completely silicified, even parts of the loops being replaced, but in most cases the shells were in fragments, and were recognised by the pores distributed over the surface, comparison being made with unchanged Brachiopoda. Viewed from the side, some are seen to be delicately costate, and they form hollow rectangular masses, only one wall of which is porous. They are sometimes of a faint red tint, having been coloured by ferruginous oxides.

(*b*) Very perfectly preserved hexagonal meshes, due to the inter-prismatic silicification of *Inoceramus*-shells, are abundant, showing columnar structure when viewed in side section.

The detrital minerals consist almost entirely of quartz, in rounded, colourless, translucent, whitish, green, and red-tinged pebbles and a number of others of most irregular form. The largest is about 1·5 mm. diameter. Masses of limonite are present, and glauconite in aggregations, which show but little trace of organic structure.

2. Residue of ·5 to 1 mm. diameter. One of the special features is the abundance and extreme angularity of the quartz, most of the grains of this mineral showing distinct traces of the original crystal form. In some the prism edges are only just beginning to be rounded off, and the pyramid faces are still evident.* Even where the pebbles are definitely rounded, they are oblong in shape, and have probably not long been derived from idiomorphic forms. Flat flakes are not uncommon, and, in addition to the translucent ones, there are a number of others of a yellowish colour.

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* Some of these may be secondary growths of quartz.

Hexagonal meshes, derived from *Inocerami*, and limonite aggregations, are also present.

3. Residue of ·25 to ·5 mm. diameter = ·704 gr. The angular grains of quartz are still numerous, but in addition to these are a few glauconite grains, and two internal casts of *Textularia* have been observed.

4. The finer residue consists of highly angular quartz, minute glauconite grains, and a number of limonite fragments. When treated with heavy liquid, sp. gr. 2·93, the limonite grains are so abundant as to obscure the other minerals, but on boiling with strong acid, they dissolve, and the remaining residue is seen to contain a large number of irregular red-brown and orange-yellow fragments of Rutile, and a number of crystals of Tourmaline of a blue-grey colour (having the rhombohedral terminations at one extremity, but flat at the other). No fragments of zircon were observed.

II. The Sample from Bed No. 13 *of Meyer.*

Original weight, after drying = 81·59 grammes.
After solution in 20 per cent. HCl there remained :—
Fine insoluble residue = 2·30 grs. = 2·82 per cent.,
Heavier coarse residue = 15·29 grs. = 18·74 per cent.,
therefore $CaCo_3$ - = 78·44 per cent.

1. Of the heavier residue 7·46 grammes were over 1 mm. in diameter, and consisted almost entirely of colourless quartz grains, displaying every type of form, from completely rounded to highly angular grains. Flattened examples are also numerous. A few have a faint greenish-yellow mineral coating parts of the surface, and probably glauconitic in nature. The largest grains are 4 mm. in diameter.

2. Particles from ·5 to 1 mm. diameter = 4·84 grs., consisting of quartz and glauconite grains in about equal proportions.

(*a*) The quartz grains are similar to those described above.

(*b*) The glauconite is mostly in the form of well-preserved casts, the chambers being still united together, and thus it marks the internal outlines of the foraminifera in which it was enclosed. Beautiful crozier-shaped forms, recalling species of *Haplophragmium*, are fairly common, but the most numerous types are those recalling species of *Bulimina*, especially *B. variabilis*, and *B. pupoides*. Species of *Cristellaria* having the pyramidal terminal chambers such as are found in *C. gibba* were also frequently observed.

(*c*) The delicate silicified tests of Foraminifera are also numerous, mostly with single chambers, but in one case a perfect specimen of *Gaudryina pupoides*, showing the primary triserial arrangement, and subsequent biserial succession is beautifully preserved.

(*d*) An interesting feature is the presence of a number of large grains of Rutile, showing crystal forms, the prism being in a few cases clearly capped by pyramidal faces of a different order. Some of the prismatic faces are strongly striated parallel to the vertical axis. Owing to the thickness of the fragments, it is difficult to determine the exact pleochroism, but changes from yellow to reddish-brown have been observed in the grains.

3. Residue between ·25 to ·5 mm. diameter. This differs from the above in the greater abundance of delicately silicified tests of Foraminifera, mostly broken, and often still filled with glauconite. Some of the glauconitic casts are well preserved, the biserial character of *Textularia* and the spiral arrangement of *Bulimina* being well illustrated by the examples obtained. The smaller varieties of the former have the casts of the chambers standing out as rectangular projections, branching alternately from opposite sides of a common stem of extreme thinness; in the latter the stem is flattened, the projecting portions arising from it after the manner of young leaves near the apex of a growing plant.

4. The lightest material differs but little from the above, but a number of heavy minerals were obtained by means of borotungstate of cadmium. These included numerous irregular deep red-brown and red fragments of Rutile, Tourmaline in good crystals, the prisms being perfect, and capped by rhombohedral terminations. In the latter, as usual, the absorption for the ordinary ray is very great; cleavage is well seen, especially in the bluish-grey varieties. Zircon is rare, two or three crystals having doubly pyramidal terminations were seen. In these the zoning is well shown, and the pyramidal terminations are very acute. In one case the simple tetragonal pyramid, without prism faces, was observed. Annular microlites occur as inclusions.

The noticeable features in connection with this bed are therefore: The predominance of the coarser residue over the more clayey constituents, in this respect differing markedly from corresponding strata further to the east; the extreme tenuity of the siliceous tests of the Foraminifera; the delicate preservation of the glauconitic casts; and the abundance, variety, and size of the heavier minerals. The results of these two analyses are tabulated on p. 293, with the chalks of this zone.

C. The Marls and Chalks of the Am. varians Zone.

Macroscopic Aspect of the Rock.

The colour and aspect of these beds vary according to the locality and the horizon from which they come, these variations being due partly to the difference in the nature of the deposit and partly to circumstances not connected with its deposition.

From Mupe Bay, South Dorset, to Kent, the lowest beds are a bluish or brownish grey, passing upward to a pale grey at the summit of the zone. In North Dorset the lowest beds are pale grey, the higher ones almost white, but as one proceeds along the northern outcrop to the north-east in Wiltshire, Berkshire, and Oxfordshire they pass to a bluish grey, the upper part being of a lighter grey colour. This continues through Buckingham, but in Bedfordshire the marl immediately above the Cambridge Greensand is again pale grey, the centre dark grey, passing to greyish-white at the summit. Still further east the colour gradually dies away, and the equivalent to the Chalk Marl of the more eastern counties is a rock nearly white in colour. This continues through Lincolnshire and and Yorkshire, till at Speeton the lowest bed is again grey.

Examples of the Chalk at Mupe Bay or Lulworth are hard and semi-crystalline, the rock being indurated with calcite; in North Dorset it is a softish marly chalk. Alternating beds of marl and soft chalk occur in this division in the Isle of Wight, Wiltshire, Berkshire, Oxfordshire, and Buckinghamshire. To the northward through the counties of Bedford and Cambridge it is a soft marl, breaking down rapidly under the influence of weather to a marly clay. These conditions die away gradually to the east-ward, till in North-west Norfolk it is a compact hard chalk, a condition which continues through Lincolnshire and Yorkshire, but as one progresses through these two latter counties the Chalk Marl is not a smooth limestone but rough, nodular, and veiny, and being usually thoroughly indurated by calcite it forms a very hard tough rock.

Local variations, such as the siliceous beds of Wiltshire and Berkshire and the Marl Rock of Bucks, will be noticed in due course.

Microscopic Aspect of Thin Sections.

Viewed in thin sections with an objective of two-thirds of an inch focus, the chalk of this zone is seen to consist of a fine calcareo-siliceous ground mass, the constitution of which is more particularly described on p. 290, and in this are scattered mineral grains and grains of glauconite, with Foraminifera, shell-fragments, and other recognisable organic materials. The proportions of these ingredients vary greatly in different localities and at different horizons in the zone.

The following is a general description of the leading features seen in a series of thin slices of the chalk of the zone of *A. varians* from various horizons, progressing from west to east.

Dorset.—All specimens from Dorset contain a large proportion of recognisable organic fragments. These consist of comminuted shell-fragments, with a coarser piece here and there. The greater part of them can generally be identified as prisms of *Inoceramus* shells, but many are doubtless derived from other species of Mollusca. "Spheres" are very abundant in some examples, while others (as at Batcombe) contain comparatively few.

Mineral grains are more abundant in South Dorset than in North Dorset. Glauconite is always present in smallish grains, which are more abundant in the lower than in the higher beds. Sponge-spicules, thin and threadlike, are seen most commonly in the hard lumps which occur all through the *Am. varians* zone of this county. The specimen 20 feet above the top of the Chloritic Marl, Mupe Bay (10), may be taken as a type. In this "spheres" are very numerous, and occupy about 40 per cent of the area of the section, shell-fragments make about 10 per cent. Glauconite occurs in exceptionally large grains, and these, with fragments of quartz, show in strong relief. The area occupied by Foraminifera is insignificant. Sponge-spicules do not occur in this specimen.

The specimen from Dogbury Hill (Cerne, North Dorset), 6½ feet above the Chloritic Marl, (11) differs little from the above, except in the amount of mineral grains and glauconite, the former being comparatively rare, while the latter are much smaller.

Isle of Wight.—The lower beds of this zone in the Isle of Wight are crowded with shell-fragments. (See Plate IV., Fig. 1.) In a specimen from 10 feet above the Chloritic Marl at Compton Bay (12) they may be estimated at 50 per cent. of the rock. Spheres are common; grains of glauconite are rather large and conspicuous, though widely separated. Mineral grains are not abundant. Sponge-spicules are present, but are not of frequent occurrence. There are more Foraminifera to be seen than in Dorset specimens, but they form a very small part of the rock; they appear to be chiefly arenaceous forms. One or two *Textularia* can be recognised, but *Globigerina* is rare.

At Culver Cliff, 10 feet above the Chloritic Marl, shell-fragments are still more abundant, and form about 75 per cent. of the rock. The fragments are nearly all prisms of *Inoceramus*, and appear to have been rolled. Glauconite is abundant, estimated at 10 per cent., mineral grains rare, "spheres" seem crowded out, a few large Foraminifera, and here and there a sponge-spicule occurs.

A specimen from the upper part of this zone at Culver Cliff presents a strange contrast: it contains scarcely a single shell-fragment, and, with one exception, such as do occur are minute. "Spheres," on the other hand, are abundant, and form at least half the rock. There are a few minute grains of glauconite widely separated, but not a mineral grain is discernible. Sponge-spicules are not visible in the sections examined, but occur in the residues.

Sussex and Kent.—A specimen from the upper part of the zone at Eastbourne shows the rock to be very full of "spheres," with a few large *Globigerinæ*, but scarcely any shell-fragments.

In the specimen from East Wear Bay, near Dover, 10 feet above the Chloritic Marl (15), shell-fragments of irregular size form perhaps 20 per cent. of the deposit; mineral grains are common, scattered irregularly through the mass. "Spheres" seem absent, and few Foraminifera other than arenaceous forms, whose outline can be traced here and there, are to be seen. There is a large admixture of inorganic matter.

Another taken from above the " Cast Bed " (16) exhibits little else than fine amorphous material, with very finely comminuted shell-fragments and minute mineral grains scattered through it. " Spheres "are again absent; one or two arenaceous Foraminifera can be seen in outline, but no others.

Wiltshire and Berkshire.—All specimens from the zone of *Am. varians* in these counties contain a large proportion of finely comminuted shell-fragments; they are small and of an even size, and form not less than 40 per cent. of the rock, and occasionally more. The chief feature is the presence of thread-like sponge-spicules, which are common and often abundant, especially in the harder examples; but another feature is the comparative rarity of " spheres." These occur sparingly in a few examples near the top of the zone, but in the majority of cases are rare. Mineral grains are present in all specimens, their size and shape corresponding to that of shell-fragments; they are not well seen until a section is viewed with crossed Nicols. The grains are distinctly more numerous than in the marl of North Dorset. In specimens from the lower beds the presence of fine siliceous inorganic material is evident.

Two samples taken from the railway cutting by Upton Scudamore, near Warminster (see p. 152) showed exceptional characters. The exposure is probably from 50 to 60 feet above the base of the zone; the one was a hard grey chalk, the other a tough brownish-grey sandy chalk. The first proved to be full of recognisable organisms and organic *débris,* such as Foraminifera, shell-fragments, spheres, sponge-spicules, a few Radiolaria, and many grains of glauconite and quartz. The coarser ingredients apparently make up nearly 60 per cent. of this rock. There is no globular colloid silica, but unaltered siliceous sponge-spicules are common. The matrix too is very full of definite calcitic crystals. The other sample is really a sandy chalk, and contains a considerable quantity of fine quartz-sand mixed with a few angular shell-fragments and a very few Foraminifera. The percentage of fine inorganic material in this bed must be large.

In North Wilts and through Berkshire beds of a peculiar siliceous chalk occur at various horizons. These contain besides the ordinary ingredients of the zone a certain amount of organic silica, partly in the form of sponge spicules, and partly as globules or discs like those which occur in the Malmstone. (See Vol. I. of this memoir.) The beds in which this colloid silica occurs are generally harder than the rest, and are sometimes very hard and compact. These siliceous beds appear to be local and to form lenticular masses which occur at different horizons and at different places. It is noticeable, too, that those beds which are less siliceous are more purely calcareous than the generality of chalk of this zone elsewhere. The sponge-spicules are usually present either in a siliceous condition or as calcite casts.

So thoroughly indurated are these beds with organic silica that when a fragment of the rock is treated with hydrochloric acid it does not fall to powder, but is held together by a network or mesh of silica. These beds have been previously described by us, and to that account the reader may be referred.*

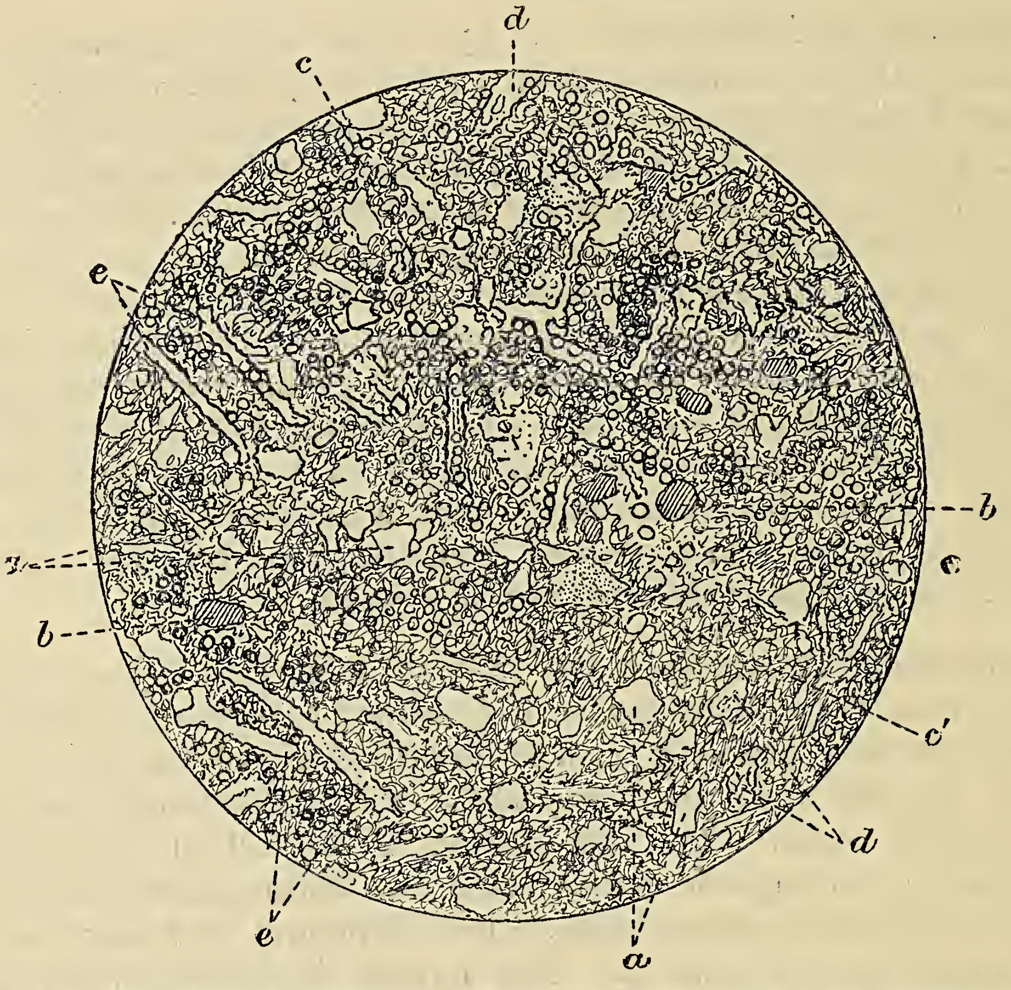

FIG. 55—Structure of Siliceous Chalk from Collingbourn Kingston in Wiltshire. (From the outside of a nodule.)

The ground mass is partly a fine calcareous mud, and partly globular silica, the latter being most abundant in the upper part of the slide. It includes; *aa* quartz-grains; *bb* glauconite grains; *cc* shell-fragments; *dd* cavities filled with silica which is partly colloid and partly crystalline; *ee* sponge-spicules replaced by chalcedonic silica. (x 50 diam).

Oxfordshire and Buckinghamshire.—Examples of this zone coming from Chilton in Berks and from Oxfordshire present uniform characters according to the horizon from which they were taken. Finely comminuted shell-fragments form from 25 to 50 per cent. of the material. "Spheres" are rare on the whole, but are more numerous in the upper part of the zone; Foraminifera occur very sparingly. Sponge-spicules of the usual thin and thread like character are to be seen in the Chilton examples. Small grains of glauconite occur in all, but are not abundant. Mineral grains are evenly distributed through the deposit; they are larger and more numerous near the base, where much fine inorganic matter is also present. The higher beds, as usual, are the most calcareous; the mineral grains become smaller and the proportion of inorganic matter less as one progresses from the base to the summit of the zone.

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* The Occurrence of Colloid Silica in the Lower Chalk of Berkshire and Wiltshire, Quart. Journ. Geol. Soc., Vol. xlv. p. 403, 1889.

Mineral grains which, judging from thin sections, reach their maximum in size and quantity between Wantage and Tring are more abundant in the lower than in the higher part. They are never very large, and do not approach the size of the mineral grains of South Dorset. So far as can be measured in the sections the dimensions do not exceed ·25 mm. in the longest diameter, though they probably exceed this.

In Buckinghamshire and extending westward also into Oxfordshire is a bed of hard compact limestone in the middle of this division. It does not differ much from the beds above and below it in general structure, but the usual ingredients are now inclosed in a matrix of granular crystalline calcite which binds the whole into a compact limestone (see p. 292). This change has doubtless been accomplished by the aid of percolating water saturated with calcic carbonate, for the "Marl Rock," as it may be termed, is the source of a continuous line of springs, the water being thrown out by a bed of argillaceous marl beneath.

Bedfordshire and Cambridgeshire.—We have no information of the composition of the lower beds of this zone in the western part of Bedfordshire. The upper 35 feet is well exposed in a cutting of the Midland Railway at Charlton, three miles east of Dunstable. The portion seen here is a dark grey marl containing a considerable quantity of fine sand, the grains of which are smaller than those of Buckinghamshire; so fine, indeed, are they that it is almost impossible to separate them from the amorphous matter by levigation. It passes up into a paler grey calcareous marl, in which there is a decided decrease in the amount of sand-grains and fine inorganic matter. Shell-fragments are fairly numerous; many are too small for identification, but the larger pieces are nearly all prisms of *Inoceramus*, though here and there plates or spines of echinoderms may be recognised. Foraminifera are sparingly distributed through the deposit. (See Plate IV., Fig. 2.)

At Arlsey, in the north-east corner of the county, the lowest beds are exposed; the aspect of the marl in a specimen 10 feet above the Cambridge Greensand (17) reminds one of that of North Dorset. "Spheres" regain their premier place, and with shell-fragments (*Inoceramus*-prisms) of irregular size form nearly half the rock. A few Foraminifera and here and there a mineral or glauconitic grain of small size constitute the recognisable elements embedded in the amorphous matrix, which in this locality and at this horizon is largely calcareous.

But nearer the summit of the zone, 30 feet below the Totternhoe Stone (18), the material is nearly identical with that seen in Charlton cutting, the recognisable ingredients being small shell-fragments, a few "spheres" and Foraminifera, and much fine sand and argillaceous matter, the sand grains being smaller than at Charlton. As at Charlton, the marl passes rapidly up to a more calcareous deposit with fewer but larger shell-fragments and a greater abundance of "spheres."

Glauconite occurs in all specimens, but the grains are small and widely separate. Sponge-spicules are not infrequently seen, but are nowhere abundant.

Passing into Cambridgeshire we find at Barrington 10 feet above the Cambridge Greensand a deposit very similar to that at Arlsey. Specimens from higher horizons show that as we pass upwards the marl loses its sandy and siliceous character, mineral grains become smaller and rarer, "spheres" more numerous and shell-fragments more irregular in size. Nearer Cambridge the same phases occur.

Norfolk and Suffolk.—In North-west Suffolk and in the south-east corner of Norfolk (Stoke Ferry, Shouldham, &c.), the amount of fine siliceous inorganic material is hardly appreciable to the eye, and sand grains are rare. In the majority of examples from the lower two-thirds of this zone fine amorphous calcareous material constitutes 75 per cent. of the deposit; "spheres," shell-fragments of irregular size, neither in exceptional abundance, a few Foraminifera and minute sand grains form the remainder. In the upper part of the zone shell-fragments and spheres are more numerous.

In North-west Norfolk (Dersingham, Snettisham, Heacham) the structure of the marl becomes more irregular in its upper part. "Spheres" are common though not abundant, and many prisms of Inoceramus shells occur in all examples. *Globigerinæ* and a few other Foraminifera occur, but they still form a very small part of the deposit. In several slides there are fragments of Hexactinellid sponge-mesh, the silica of the spicular walls being replaced by calcite.

The lateral passage from a marl to a chalk culminates at Hunstanton. Here the successive portions of the zone exhibit well-marked differences of structure, viz., the "Sponge Bed," the "Inoceramus Bed," and the white hard beds which lie between this last named and the Totternhoe Stone.

Of the Sponge Bed (20) rather more than half consists of fine amorphous material, once probably a fine calcareous mud, but now in a condition of finely granular crystalline calcite. "Spheres" are abundant at the base of the bed, less so towards the top. Foraminifera, though not numerous, are well shown in outline, and amongst them the form of a *Globigerina* is prominent. These with the cells and "spheres" form about 30 per cent. of the deposit. Shell-fragments scattered through the mass form perhaps 10 per cent. of it. Here and there are large quartz grains perhaps derived from the underlying Red Chalk; glauconite is rare. A single rod-like sponge spicule and a fragment of Hexactinellid mesh is seen in one of the slides.

The Inoceramus-Bed (21) is practically a shell-sand, consisting chiefly of Inoceramus-prisms (entire or broken) with fragments of the shell itself showing the prismatic structure. Foraminifera are common; *Globigerina, Textularia,* and various forms of *Rotalina* can be distinguished. Small grains of glauconite are present, and this mineral can be seen infilling the tests of the Foraminifera. The whole is cemented by fine granular crystalline calcite.

A slide of the Chalk midway between the Inoceramus Bed and the Totternhoe Stone (22) shows the coarse ingredients of the rock to be "spheres," with which are numerous Foraminifera. Many of the latter are probably arenaceous forms, but *Globigerina* can be recognised, and somewhat coarse shell-fragments are conspicuous. The actual area occupied by recognisable organisms is not more than 25 per cent. of the whole rock. The shell-fragments occur very irregularly or in patches, some parts of the sections being full of them, in other parts they are absent. No glauconite or other mineral grains are visible in the slides.

Lincolnshire and Yorkshire.—The aspect of thin sections from the *Am. varians* zone in these counties is similar to that of Hunstanton. In general aspect the Sponge Bed continues nearly the same through Lincolnshire, but in Yorkshire it becomes inseparable from the Red Chalk. The Inoceramus-Bed can be followed through Lincolnshire and Yorkshire; the specimens examined differ but little from that of Hunstanton, except perhaps that the shell-fragments are more irregular in their distribution and even coarser in the more northern examples.

In the higher beds shell-fragments show the same curious irregularity, occurring either in patches or in thin veins which may extend across a thin section of the rock. Nearly all may be referred to Inoceramus-shell. Of the Foraminifera *Globigerinæ* are sufficiently common to form a distinctive feature, species of *Textularia* and *Rotalina* are not of infrequent occurrence, while a coiled test (probably *Ammodiscus*) can be often made out. The proportion of Foraminifera to the mass of the rock continues to be very small.

In many specimens from Yorkshire and Lincolnshire, and in a few from North-west Norfolk, there occur ill-defined spheres which bear a strong resemblance to the tests of Radiolaria, but their characters are so much obliterated that it is not possible to speak positively. The most abundant form is similar to that figured in Q.J.G.S. Vol. li. Plate xxii., Fig. 1. Sponge-spicules are of rare occurrence.

It only remains to record the lower beds of this zone at Speeton (See p. 230). In that immediately overlying the Red Chalk (23) fine inorganic sediment again appears to be mixed with the calcareous mud, and is accompanied by fine sand. "Spheres" are still abundant, Foraminifera occur, and are chiefly *Globigerinæ* with a few species of *Textularia* and *Rotalina.* Shell-fragments are rare. Glauconite seems absent. The bed passes up into normal Chalk-Marl of the Yorkshire type which, though stained a deep red, differs in no other way from the ordinary rock at this horizon. Above this the marl becomes shelly, (25) and for 8 or 10 feet very coarse shell-fragments abound, especially in the material which surrounds the nodule-like masses in the bed. This condition gradually passes away upward, and the desposit again assumes its normal character, and consists largely of fine amorphous matter with a few "spheres," *Globigerinæ* or other Foraminifera with shell-fragments of irregular size.

Examination of the Washings.

Under this heading we give a description of the chief features of the coarser materials obtained by washing the various specimens, including the Foraminifera obtained from the coarser residues after the action of the acid solution.

Little information could be obtained by this means from the hard indurated chalk-marls of the West of England or the hard chalk of this zone in Lincolnshire and Yorkshire, but from the softer marls of Kent, those of Charlton and Arlsey, in Bedfordshire, and that from Barrington, in Cambridgeshire, better results were obtained. The coarser organic ingredients were practically the same in all localities, though they differed slightly in the relative abundance of the various organisms. The following remarks refer especially to those softer beds, unless other localities are mentioned.

Shell-fragments.—These were chiefly prisms of Inoceramus-shell, or larger fragments showing the prismatic structure; here and there a bit of *Pecten, Rhynchonella, Ostrea,* or *Plicatula* could be detected. Small Echinoderm spines occurred in them all, but were most numerous in the marl from Barrington, Cambridgeshire, ten feet above the Cambridge Greensand. They may be referred to *Hemiaster* or *Pseudodiadema.* Fragments of Bryozoa are also fairly numerous.

Sponge Spicules.—The spicular remains of sponges, are never very numerous except in the beds referred to on p. 279. Hexactinellid mesh, with both Tetractinellid and Monactinellid spicules occur in the marls of South Dorset, and the Isle of Wight, (Compton Bay). Between the West of England and north Norfolk spicules are comparatively rare, though in the lower part of the Marl at Dover both Tetractinellid and Monactinellid spicules occur. Rods of glauconite which are probably casts of spicular canals are sometimes common. Dr. Hume* has recognised a single Lithistid spicule in the Chalk-Marl of Culver Cliff, Isle of Wight, and here the *Hexactinellidæ* are represented also.

Hexactinellid mesh occurs again in the Chalk-Marl of Norfolk and in the Sponge Bed of Hunstanton, and single spicules (of uncertain affinities) are also to be seen in thin sections of this rock. Here, however, the siliceous wall of the spicule is replaced by calcite. None occur either in washings or residues. In the Chalk Marl just above the Cambridge Greensand at Arlesey several fragments of Hexactinellid mesh occurred, the silica either replaced by or coated with limonite.

Coprolites—The chalk of Mupe Bay, up to 20 feet above the top of the glauconitic marl, contains minute phosphates of various shapes. They are not very numerous. Some are elongated cylinders with annular ring-like markings; these are now regarded as the excreta of fishes; others, shaped something like an acorn, remind one of the larger examples found in the Grey or Middle Chalk; others again are small ovoid bodies. The last occur in almost all marls. Fish teeth and scales are rare.

Clear, round, reddish-brown grains occur in nearly all specimens near the base of the Marl, but are less common at the summit. They are referred to by Dr. Hume,† who says: "M. Laxne has carried out some analyses which lead him to the conclusion that these were probably glauconite, and that the color is due to alteration, a view which would also be strengthened by the similarity of occurrence in both cases." The external appearance of these grains is smooth and glassy; in the chalk of Mupe Bay similar material occurred in elongate form with a central constriction. Rarely grains of similar shape, white and glassy or with slight cloudiness, were observed.

Foraminifera.—Including seven species already recorded from the Chalk Marl of Folkestone by Mr. Chapman‡, the total number obtained from this zone is 116. A list of these species and their distribution will be found on p. 329. They were identified by Mr. Chapman, and according to Dr. Brady's classification belong to the following genera and families:—

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*Chemical and Micro-Mineralogical Researches on the Upper Cretaceous Zones, by W. T. Hume, p. 21.

† Hume, *op. cit.*, p. 24.

‡ The Foraminifera of the Gault of Folkestone, Journ. Roy. Mic. Soc. (1898), page 40.

Family.	Genera.	No. of Species.	—
Miliolidæ	Nubecularia	2	Both new species.
	Spiroloculina	2	
	Miliolina	2	One new species.
Astrorhizidæ	Rhizammina	2	One ,, ,,
Lituolidæ	Reophax	5	One ,, ,,
	Haplophragmium	8	One ,, ,,
	Ammodiscus	4	One ,, ,,
	Trochammina	2	One ,, ,,
Textulariidæ	Textularia	10	One distorted.
	Verneuilina	1	
	Tritaxia	2	
	Spiroplecta	2	
	Gaudryina	6	One new species.
	Bulimina	12	
	Bolivina	1	
	Pleurostomella	2	One new species.
Lagenidæ	Lagena	2	
	Nodosaria	12	
	Frondicularia	3	
	Flabellina	1	
	Rhabdogonium	3	
	Marginulina	5	
	Vaginulina	4	
	Cristellaria	8	One new species.
	Polymorphina	5	
	Ramulina	2	
Globigerinidæ	Globigerina	2	
Rotaliidæ	Discorbina	1	
	Anomalina	2	
	Truncatulina	1	
	Rotalia	2	

Of the 116 species which have been obtained eighty-eight are recorded by Mr. Chapman as occurring in the Gault, sixteen do not occur in that deposit, and twelve are new. The greatest number of species came from the soft marls of Folkestone and the Midland counties (Bedfordshire and Cambridgeshire), for little was done by washing the specimens of the indurated rocks of Dorset, the Isle of Wight, Norfolk, Lincolnshire, and Yorkshire, so that our knowledge of the Foraminifera of these districts is confined to the acid residues. These, however, gave some remarkable results, for it was clearly shown that from North-west Norfolk to Speeton the arenaceous Foraminifera were of different character to those contained in this zone in the south.

The characteristic forms of this zone in North-west Norfolk, Lincolnshire, and Yorkshire were *Ammodiscus incertus*, *Ammodiscus charoides*, and *Ammodiscus gordialis*, all common as a rule. With these were associated *Rhizammina* sp. *Reophax nodulosa*, not seen in southern samples, and *Spiroloculina asperula*. Species of *Textularia*, abundant in the south, are here absent, with the exception of *Textularia trochus*; *Bulimina* too is comparatively rare, though a few of the commoner varieties occurred; *Haplophragmium acutidorsatum* was found in every sample of this zone at Speeton, but was not noticed in the south; and *Gaudryina filiformis* and *Gaudryina pupoides* (common in the south) are rare at Speeton.

Of the forms which occurred most commonly in the acid residues of this zone in the southern and western counties, the most abundant were *Bulimina Presli* and its variety *sabulosa*, with *Bulimina brevis*, *B. obtusa*, and *B. affinis*. *Gaudryina pupoides* was very common in every southern sample, *Tritaxia tricarinata* occurred in every sample, and *Tritaxia pyramidata* was also frequently noted, but neither species occurred in Norfolk and to the north of the Wash. Of the genus *Textularia*, *Textularia trochus* and *Textularia turris* were most regular in their occurrence, *Textularia prelonga* and *Textularia minuta* being next in order of frequency. *Ammodiscus incertus*, though occurring in the upper part of the zone at Folkestone and Arlesey was by no means common. Portions of the test of *Reophax*, built of very coarse particles of sand, were common in the acid residues of samples of this zone from Mupe Bay, especially in the lower part of it, and a few of similar character were found in the base of the zone at the Isle of Wight. The two species of *Spiroplecta* again occurred in the Dorset specimens, and were not noticed in those to the eastward.

The whole of the Lagenidæ, Globigerinidæ and Rotaliidæ were obtained from four specimens of the zone taken from the following localities: Folkestone, Charlton cutting on the Midland Railway (a few miles north of Luton), Arlesey in Bedfordshire, and Barrington in Cambridgeshire. In the first and last of these localities the specimens came from the base of the zone; those from Charlton and Arlesey, near the top of it. The species of these families seemed fairly distributed throughout the deposit, and it cannot be said that any particular part of the zone was especially characterised by the occurrence of any one form or forms. *Cristellaria gaultina* was the most common form of the family Lagenidæ, *Cristellaria planiuscula* coming next in the regularity of its occurrence. *Rhabdogonium excavatum*, *Marginulina glabra*, *Polymorphina fusiformis*, and *Ramulina aculeata* occurred in all specimens from the above-named localities. *Globigerina cretacea* were common; the tests, though fairly large, are not so fine as those of the Middle Chalk. Of the Rotaliidæ, *Anomalina ammonoides* and *Rotalia Soldani* were most frequent in occurrence.

Ostracoda.—The valves of Ostracods are very abundant in some specimens of the chalk of this zone; they were especially so in the specimen from 10 feet above the Cambridge Greensand at Barrington, Cambridgeshire. The following is a list of those species isolated which were examined and identified by Mr. Chapman.

Pontocypris bosquetiana (*Jones.*)
Bairdea subdeltoidea (*Münster*).
,, harrisiana (*Jones*).
Bythocypris Brownei (*Jones.*)
Cythereis triplicata (*Römer*).
,, auriculata (*Cornuel*).
,, ornamentissima (*Reuss*).
,, ,, var. paupera (*J. and H.*).
Cytheropteron concentricum (*Reuss*).
,, alatum. (*Bosquet*)
,, umbonatum (*Will.*)
Cytherella ovata (*Römer*).
,, obovata (*J. and H.*).
,, Muensteri (*Römer*).
,, Williamsoniana (*Jones*).

Examination of the Residues.

Detrital Minerals.—As before, the detrital minerals here referred to are those which occurred in the coarse portion of the acid residues, from which the percentages and measurements were taken.

Quartz is always the most abundant of the detrital minerals. In general appearance and characters the grains do not differ from those in the basement beds. Referring to the grains in the Chalk Marl of Culver Cliff, Isle of Wight, Dr. Hume* says they consist of "highly angular fragments of a beautiful water-clear transparent type;" other grains present crystal faces, though it is not usual to obtain a perfect crystal. In one case a very delicate prism capped by rhombohedral faces has been observed. We also have met with one or two such grains. He also notes that some of the grains had lost their clear character, having become coated with a ferruginous oxide. In referring to the Chalk Marl of East Wear Bay, near Folkestone, he says the quartz differs little from that previously described from the Isle of Wight.

The largest amount of detrital minerals is again found in the most westerly specimens. In one sample taken 10 feet above the glauconitic marl at Mupe Bay, they are estimated to form 6 per cent. of the material examined; further eastward they diminish considerably, and in a specimen 10 feet above the Chloritic Marl in the Isle of Wight they form only 0·8 per cent. of the material, and at Dover at the same horizon 0·2 per cent. At the same horizon at Arlesey, Bedfordshire, the grains in a residue from 50 grammes of material could almost be counted on the fingers. The quantity of detrital minerals diminishes rapidly upwards. At Mupe Bay, 20 feet above the glauconitic marl, they form only 0·2 per cent. of the material examined; at Dover, at nearly the same horizon, only 0·03 per cent. The percentage of detrital minerals to the east and north-east of this is infinitesimal.

The largest grains occur at Mupe Bay, and, as in quantity so in size, they diminish rapidly upwards. Their average size in this locality 10 feet above the Chloritic Marl was ·19 mm. with a maximum of 1·2 mm., and 20 feet above it the maximum was ·83 mm., average ·13 mm. At Dover, however, while as a whole the grains are smaller, averaging only ·07 and ·08 respectively 10 feet and 25 feet above the Chloritic Marl, the larger grains occur in the higher bed, the maximum being ·51 mm. 25 feet above the Chloritic Marl and ·37 mm. 10 feet above it.

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* Chemical and Micro-Mineralogical Researches by Dr. Hume, p. 25.

Farther east the amount of the detrital minerals is exceedingly small in comparison with the bulk of the Chalk, but quartz grains measuring not less than ·20 mm. in their longest diameter occur in nearly every specimen. In the Sponge-Bed of Hunstanton grains measuring 1 mm. are to be found. Neither Dr. Hume nor I have observed aggregations of quartz grains similar to those described by M. Cayeux from the Upper Turonian of France.*

For the general report by Mr. J. J. H. Teall, F.R.S., on the Detrital Minerals of the Lower Chalk, see p. 311.

Secondary Minerals.—Glauconite.—On modern sea floors this mineral is usually associated "with the minuter fragments of the rocks and minerals of continental lands," and "its greatest development takes place where fine muddy particles commence to make up a considerable portion of the deposit." In the zone of *Am. varians* it occurs most abundantly in the sandy Chalk Marl of Mupe Bay, where it is estimated to form 3 per cent. of the rock 10 feet above the glauconitic marl, though at 20 feet above the proportion is little more than 0·5 per cent. the amount diminishing upwards as the detrital minerals become scarcer.

It continues to occur sparingly throughout this zone, and was found in specimens obtained from the cliff-sections of the south-coast and in all counties south-west of Cambridgeshire, the grains being small and widely separated in the rock, but to the northward they become very scarce, and are finally almost entirely confined to the Sponge-Bed and Inoceramus-Bed of Hunstanton. In Lincolnshire and Yorkshire, it becomes still more rare.

Except in the lowest beds of this zone, and in the Inoceramus-Bed of Hunstanton, casts of Foraminifera in glauconite are uncommon. At Mupe Bay the larger grains are rough and mammillated and resemble those of the Chloritic Marl, but most of the grains seen in this zone are small and rounded, and vary in colour from a dark olive-green to a pale green.

Their maximum size approximates closely to those of the detrital mineral grains. The largest measured was ·80 mm., in its longest diameter, and occurred in the lowest specimen of the marl from Mupe Bay, in which locality the average size was ·31 mm. In the remainder of this zone the maximum size scarcely ever exceeds ·55 mm., the majority of the grains measuring from ·10 mm. to ·15 mm.

Marcasite.—Small brassy nodules of this mineral occurred in only two or three instances. They were found in the specimens from Lydden Spout, near Dover, and from Arlesey in Bedfordshire, both as rounded irregularly-shaped nodules, lengthy cylinders or minute spherules. At Speeton it occurred as beautifully-formed octahedral crystals or small nodules, consisting of such crystals fused together.

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* Contrib. à l'etude microgr. des. Terr. Sed. p. 336 (1897).

† "Challenger" Reports, Deep Sea Deposits, p. 313.

Limonite.—Small nodules or irregularly shaped masses or nodules of brown ferruginous material occurred in nearly every specimen. The nodules were either minute spheres or cylinders with a brownish crust and darker interiors or irregular masses of porous brown iron oxide, the latter easily crushed to powder. They are probably derived from the alteration of Marcasite, for Dr. Hume* found a nucleus of this latter mineral remaining in some of them. Limonite not infrequently encrusts the spicules of sponges, and is occasionally seen forming casts of Foraminiferal tests.

Finest Material.

The finest material of the Chloritic Marl and of the zone of *Am. varians* is in these pages generally termed the amorphous matrix, and by M. Cayeux it is called the "ciment." It surrounds and includes the recognisable particles contained in the rock. When separated from the coarser particles by levigation, it reflects in its constitution the varying characters of the marls from different localities. Thus in sandy or glauconitic marls minute mineral and glauconite grains will be found to be numerous, while in very marly examples extremely fine inorganic matter preponderates, and the amount of calcareous material is small. That part of the amorphous material which is acted on by the acid solution, and which appears to be largely, if not altogether, of organic origin, is of similar nature both in the Chloritic and Chalk Marl, and may be thus described. It consists of (1) particles which behave with polarised light as calcite, and are probably of organic origin, (2) particles of calcite which seem to be of subsequent formation, and (3) exceedingly fine matter, presumably of inorganic origin, the particles of which are hardly discernible even with high powers.

The first division may be further sub-divided into (*a*) flat particles of irregular shape, their edges frequently angular, usually showing an indefinite internal structure and sometimes a fine striation. These are presumably minute fragments of shell; (*b*) very thin fragments, not infrequently perforate, which seem to be derived from foraminiferal tests. Many washings contain also a number of very minute Foraminfera, chiefly *Globigerina* and *Textularia*, and minute "spheres;" (*c*) minute calcite particles which as a rule give no clue to their derivation, though some can be recognised as broken pieces of crystalloids.

(*d*) *Coccoliths.*—Minute oval bodies which are frequently referred to as Coccoliths, sometimes as crystalloids, form a very important part of the finest material, though their apparent abundance is not so great in this lowest division as in the higher beds of the Chalk.

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* Micro-Mineralogical Researches, p. 43.

They have been noticed by many writers—by Ehrenberg, Huxley, Wallich, Sorby, and others; and different opinions have been expressed as to their nature and derivation.

Recently, however, Messrs. Murray and Blackman* have investigated the characters of Coccoliths and Rhabdospheres, and have come to the conclusion that "by far the larger number of bodies described by geologists as Coccoliths have no claim to be so considered." "There is no evidence that they are derived from even allied organisms."

The result of their investigations is to show that Coccoliths possess a well marked structure—viz., two limbs joined together by a central collar: "The real test of a Coccolith is thus in its double structure." They recognise two distinct forms which emanate from two species of Coccospheres. One is circular in outline with a small central pore, *Coccosphæra leptopora*; the other is oval with a central depression and a fairly large central aperture, sometimes cut into two D-shaped apertures by a cross bar of calcareous material, *C. pelagica.* The rims of both are usually ornamented by fine radiate striæ.

Examination of the finest dust from the Chalk Marl mounted, as recommended by these authors, in strong glycerine will show that, judged by the above standard, very few, if any, of the oval and round forms which abound in the deposit can be considered Coccoliths. The forms seen are oval, many have a central oval marking corresponding with the outline of the rim and are crossed by a central bar, in others the bar is absent. Viewed edgewise they appear like a watch-glass in shape, some are mere discs, but others have a greater thickness, and in such around the centre of the periphery may be seen a divisional line, but the true shirt-stud form was not detected. In many, however, the details of markings and structure are much obscured by calcitic crystals which adhere to them. It is, however, difficult to believe that at least some of these forms, whose ornamentation and general appearance is remarkably like the true Coccolith, are not derived from organisms of a similar nature to the Coccosphere of to-day. Circular forms with a round central marking are also abundant. Rhabdoliths are not uncommon, and some of the circular forms appear to be the upper and funnel-shaped part of the Rhabdolith, the stalk being broken off. Messrs. Murray and Blackman have figured several specimens of "spurious" Coccoliths from the Chalk Marl, and also a Rhabdolith.

(2) Crystals of calcite of irregular subangular, or rounded outline, clear and structureless, and differing in general appearance from those supposed to be shell-fragments. Such crystals are abundant in all washings, and must have been formed after the deposition of the chalky mud. The process by which many Chalk Marls

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* Murray and Blackman, Phil. Trans. Roy. Soc., Ser. B, Vol. cxc. p. 436.

and Chalks become hardened seems to be due to the gradual growth of these minute crystals. In many samples the arrangement of these minute crystals suggests that they have continued to increase until they have enclosed the coarser ingredients of the mass, and interlocking with each other have converted the whole into a compact semi-crystalline rock. The crystalline grains vary in size from very minute particles to such as pass into broader crystals. When developed in abundance, as in some of the harder and purer chalks, they give a granular aspect to a slice of the rock under the microscope, and this material will hereafter be described as "granular crystalline calcite."

(3) The exceedingly fine inorganic material (clay) present in considerable proportions in the Chloritic and Chalk Marls can scarcely be recognised when a portion of the finest washings are distributed on a slide and mounted in Canada Balsam, though its presence gives a greyish tint and a general appearance of dirtiness to the deposit. In the finest part of the residue which results in the treatment of specimens of this division by dilute acid it can be seen as structureless amorphous material. It resembles the amorphous material of the Gault already described,* but differs in one important particular. It is neutral when viewed with polarised light like that of the Gault, but the "many points of light," the "ill-defined crypto-crystalline appearance, as though particles of quartz had become entangled in the amorphous matter," are not so evident, and though the material does appear to contain within it minute mineral particles, these are far less numerous than in the Gault clays.

Tabulation of Results.

In the annexed table will be found the results of the treatment of nineteen specimens of this zone by the acid solution. Two of these are from notes which Dr. Hume has kindly allowed us to make use of, and two others are extracted from the published work, "Chemical and Micro-Mineralogical Researches," by Dr. Hume.

We have to thank Mr. Chapman for kindly sending us a specimen from 10 feet above the Chloritic Marl, Dover, and Mr. Lamplugh for the specimens from Hunstanton; the remainder were obtained by ourselves.

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* Cretaceous Rocks of Britain, Mem. Geol. Survey, Vol. i. p. 355.

RESIDUES.—ZONE OF AMMONITES VARIANS.

Number.	Locality.	Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Colour of Residue.	Coarse Residue.											Remarks.
								Detrital Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Secondary Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Foraminifera.	Estimated per cent.	Shell fragments, indeterminable matter, &c.	
7	*Devon. Beer Bay, hard limestone overlying Upper Greensand.	gr'ms. 65·95	92·88	5·33	1·78	7·11	—	Quartz, rutile, Tourmaline.	—	mm —	mm —	Glauconite, Limonite.	—	mm —	mm —	Textularia	—	—	Silicified shell fragments common. Largely prisms of *Inoceramus* and fragments of Brachiopod shells.
8	*Bed 13 of Mr. Meyer.	81·59	78·44	18·74	2·82	21·56	—	Quartz, rutile, zircon, Tourmaline.	—	—	—	Glauconite	—	—	—	Textularia, Gaudryina, Bulimina.	—	—	This residue is chiefly remarkable for the number of silicified foraminiferal tests or casts of them in glauconite.
9	South Dorset. Mupe Bay, about 10ft. above chloritic marl.	38·457	72·73	11·82	15·45	27·27⅞	Dark brownish grey.	Quartz, felspar, zircon, microline, garnet, rutile, ilmenite, Tourmaline, Orthoclase.	53·18	1·2	·19	Glauconite	32·69	·80	·24	Reophax, Textularia, Verneuilina, Tritaxia, Spiroplecta, Bulimina, Gaudryina.	14	—	Hexactinellid, Tetractinellid, and Monactinellid sponge-spicules present; common, but not abundant. The arenaceous foraminifera large bold specimens. *Reophax* common, chiefly in fragments. (Spheres are numerous; shell-fragments common, but hardly abundant; calcareous particles, foraminifera, and spheres 55 per cent.)
10	Mupe Bay, 20ft. above the chloritic marl.	52·324	80·71	3·27	16·02	19·29	Grey	Same as above, except zircon, oligoclase probably present.	68·9	·83	·13	Glauconite	21·6	·54	·14	Reophax, Tritaxia, Spiroplecta, Textularia, Bulimina, Gaudryina.	9·5	—	Fragments of *Reophax* less common than in the last specimen; Hexactinellid sponge spicules present; a few silicified Inoceramus prisms. (Spheres abundant, calcareous particles less numerous than in the last; these, with foraminifera, about 50 per cent.)
11	North Dorset. Cerne Abbas, 6½ft. above the chloritic marl.	59·981	85·27	4·62	10·11	14·73	Pale grey.	Quartz - -	67·7	·73	·09	Glauconite	20	·53	·24	Tritaxia, Textularia, Gaudryina.	11·4	0·9	*Reophax* absent. Many short lengths of arenaceous tubes (? *Rhizammina*) are included in the estimation of the amount of foraminifera. No spicules observed, but a few short, rod-like lengths of glauconite may be residuary spicular canals. Some silicified shell fragments, Inoceramus prisms, &c., and some indeterminable particles.

* From notes by Dr. Hume.

RESIDUES.—ZONE OF AMMONITES VARIANS.

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Colour of Residue.	Detrital Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Secondary Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains-	Foraminifera.	Estimated per cent.	Shell fragments and indeterminable matter.	
12	Isle of Wight. Compton Bay, 10ft. above the chloritic marl.	gr'ms. 64·173	73·25	1·44	25·31	26·75	Pale grey.	Quartz - -	59·7	mm ·67	mm ·11	Glauconite	18	mm ·51	mm ·14	Nebucularia, Reophax, Haplophragimum, Textularia, Tritaxia, Bulimina, Gaudryina.	20	3	*Hexactinellid*, *Tetractinellid*, and *Monactinellid* sponge spicules present, and a considerable part of the glauconite is in short, rod-like lengths, silicified shell fragments and aggregations of fine siliceous matter. (Spheres, shell fragments, calcareous particles, and foraminifera estimated at 50 per cent.)
13	*? 20ft. to 25ft. above the chloritic marl, Culver Cliff.	79·29	60·20	·767	39·03	39·80	—	Quartz, jasper, tourmaline, garnet, Apatite, rutile, zircon.	—	—	—	—	—	—	—	Textularia, Tritaxia, Placopsilina, Bulimina, Gaudryina.	—	—	*Hexactinellid* mesh rare. A single *Lithisthid* spicule found.
14	† Zone A. varians.	79·33	55·15	·765	44·09	44·85	—	Quartz, tourmaline.	—	—	—	Glauconite, pyrite, Marcasite.	—	—	—	Haplophragmium, Textularia, Bulimina.	—	—	The glauconite grains are small, the mineral often seen in filling tests of Bulimines. Glauconitic rods absent; one isolated spicule of Tetractinellid character noted.
15	Kent. Folkestone, near Lyddon Spout, 10ft. above the chloritic marl.	50·378	62·70	1·35	35·95	37·30	Dark grey.	Quartz -	20·1	·37	·07	Glauconite Marcasite Marcasite, ? oxydized	24·7 1·7 2	·10	·05	Tritaxia, Textularia, Bulimina, Gaudryina.	48·3	3·00	Only two or three grains, either mineral or of glauconite, of maximum size, the remainder very small. Many casts of small foraminifera in glauconite, and a few rod-like lengths, probably residuary spicular canals. The Marcasite is in cylindrical lengths, with a few spherules; many of these appear to have become oxidized. A number of silicified shell-fragments, chiefly of *Inoceramus*. No spheres. (Foraminifera and calcareous particles, 20 per cent.)

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* "Chemical and Micro-Mineralogical Researches," page 25.

† "Chemical and Micro-Mineralogical Researches."

16	Folkestone, near Lyddon Spout, about 35ft. above the chloritic marl.	62·108	77·87	·17	21·96	22·13	Rather dark grey.	Quartz	2·0	·51	·08	Glauconite Marcasite	1·0 7·0	·35	·24	Rhizammina, Haplophragmium, Ammodiscus, Textularia, Tritaxia, Bulimina, Gaudryina.	90	—	The Marcasite is in round, elongate, or cylindrical masses, and a few spherules, brassy looking, but rather dark in colour. (Spheres absent; small shell fragments, calcareous particles, foraminifera, &c., estimated at 12 per cent.)
17	Beds. Arlsey, about 10ft. above the Cambridge Greensand.	50·289	75·62	·31	24·07	24·38	Grey	Quartz	2·0	·32	·10	Glauconite Limonite and brown porous Iron oxide	16 15	·40	·27	Miliolina, Haplophragmium, Textularia, Tritaxia Bulimina, Gaudryina.	65	2	Very few grains of maximum size, Sponge spicules common, Hexactinellid and Monactinellid forms recognised, and one or two pieces looked like fragments of a Lithisthid spicule. Limonite had entirely encrusted or replaced the spicular walls, and several casts of foraminifera were noticed in this material. (Spheres common, those with Shell-fragments and Foraminifera estimated about 20 per cent.)
18	45ft. above the Cambridge Greensand.	41·579	53·81	·20	45·99	46·19	Dark grey	Quartz	—	·50	—	Glauconite, Marcasite.	—	—	—	Tritaxia, Pleurostomella, Ammodiscus, Textularia, Bulimina, Gaudryina.	—	—	Minute mineral grains very abundant in these two specimens, but so small that separation proved impossible. One grain of quartz in the lower specimen measured ·5 mm., and three others in the higher averaged ·2 mm. In No. 18 there were a few grains of glauconite and some cylinders of Marcasite. Hexactinellid sponge mesh was observed in both. Such coarse residue as was separated was almost pure foraminifera. (Foraminifera numerous in washings, Ostracods of frequent occurrence, short lengths of Bryozoa common, a few fish teeth and coprolites.)
19	67ft. above the Cambridge Greensand.	56·274	64·54	·10	35·26	35·46	Dark grey	Quartz	—	·22	—	—	—	—	—				
20	Norfolk. Hunstanton, Sponge Bed.	54·810	95·13	·14	4·73	4·87	Pale brown	Quartz (one grain 1·3 mm. × ·9 mm.)	8·	·43	·27	Glauconite, Iron oxide.	1 10	·31	·10	Rhizammina, Haplophragmium, Ammodiscus, Bulimina.	80	—	The grains of glauconite are minute and rounded, a few are casts of foraminifera. The iron oxide is either in irregular masses of pale brown colour or in rounded nodules (? Oxidized Marcasite). Resinous grains common. (Many Spheres, Hexactinellid mesh seen in thin sections. Calcareous particles, Foraminifera and Spheres 40 per cent.)

RESIDUES.—ZONE OF AMMONITES VARIANS.

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Colour of Residue.	Detrital Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Secondary Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Foraminifera.	Estimated per cent-	Shell fragments and indetermin-able matter.	
21	Norfolk, Hunstanton. Inoceramus Bed.	gr'ms 55·692	91·68	·17	8·15	8·32	Grey	Quartz -	3	mm ·30	mm ·14	Glauconite, Porous iron oxide.	60 10	mm —	mm —	Bulimina, Gaudryina.	25	2	Much of the glauconite occurred as foraminiferal casts, those of *Globigerina* being very common. Mineral grains scarce. (Shell-fragments coarse and abundant; chiefly broken prisms of *Inoceramus*, 80 per cent).
22	Hunstanton, 6ft. to 8ft. below the Totternhoe Stone.	59·919	96·97	·01	3·02	3·03	Pale grey	Quartz -	—	·15	—	Glauconite	—	·18	—	Rhizammina, Haplophragmium, Trochammina, Bulimina, Gaudryina.	—	—	Mineral and glauconitic grains rare, such coarse residue as was separated consisted chiefly of the debris of arenaceous foraminifera. (Calcareous fragments, Spheres and Foraminifera about 20 per cent).
23	Yorkshire, Speeton, Bed 2, about 3ft. above the Red Chalk.	84·726	71·16	·73	28·11	28·84	Rather pale grey	Quartz -	4	·27	·09	Glauconite (rare), Marcasite -	10	·05	—	Spiroculina, Rhizammina, Reophax Haplophragmium, Ammodiscus, Textularia, Bulimina, Gaudryina.	85	1	Marcasite occurs in brilliant metallic crystals, many of which are octahedra, and aggregations of such forms. Only half a dozen grains of glauconite were observed. A few spicular fragments.
24	Bed 3, the lowest Red band.	73·661	84·16	·31	15·53	15·84	Red	Quartz, a few grains only	—	·29	·11	Marcasite -	1	—	—	Spiroculina, Reophax, Haplophragmium, Ammodiscus, Trochammina, Gaudryina, Bulimina, Pleurostomella.	95	4	This residue consisted almost entirely of arenaceous Foraminifera or their débris, with a little Marcasite. Some flat siliceous flakes and aggregations of siliceous matter not, apparently, connected with the foraminifera.
25	Half way between Bed 3 and the "Grey Bed."	84·627	94·949	·013	5·038	5·051	Pale grey	Quartz -	—	·21	·12	Glauconite	—	·29	—	Haplophragmium, Ammodiscus, Textularia, Bulimina.	—	—	A few grains of glauconite, all of largish size. Resinous globules very common in this specimen. (Shell fragments numerous and coarse; these, with foraminifera, &c., form about 75 per cent. of the rock.)

Summary of Chemical Results.

In this zone the proportion of material insoluble in the acid solution is on the whole considerably less than in the Chloritic marl, but the results of the analysis of the specimens appear at first sight irregular, not only when the zone is considered laterally from west to east, but also when considered in different localities in vertical section, the percentage of insoluble matter ranging from 3·03 per cent. at Hunstanton to 46·19 per cent. at Arlesey, in the latter case in the upper part of the zone.

The specimens from the West of England contain by far the largest proportion of coarse ingredients. In the two samples of the quartziferous limestones of Devonshire analysed by Dr. Hume, the coarse particles, *i.e.*, sand grains, glauconite, silicified shell-fragments and foraminifera amount to 5·33 per cent. and 18·74 per cent. respectively. Though there is so large a proportion of coarse material, the clayey residue is comparatively small, the analysis showing that only 1·78 per cent. and 2·82 per cent. of fine matter is present in the two samples. Two specimens obtained from Mupe Bay at 10 feet and 20 feet above the base of the zone also contain a large amount of coarse material, the percentage being 11·82 per cent. and 3·27 per cent. respectively, the analysis showing a progressive decrease of coarse matter upwards, but this decrease is only in the coarse material, for there is a slight increase (5 per cent.) in the proportion of the clay.

Taking the results of the analysis of a series of specimens which are given below, we see that the coarse part of the residue diminishes from west to east, but the percentage of fine material, the clay of the deposit, while showing a tendency to drop between Mupe Bay and Cerne, rises at the Isle of Wight and again at Folkestone, then decreases northward at Arlesey and again at Barrington, and becomes very small at Hunstanton. From the evidence of thin microscopic sections this condition of things continues to north-east Yorkshire, where at Speeton there is again an increase of mud.

10 ft. above the Base of the Zone.	Mupe Bay.	Cerne.	Isle of Wight.	Folkestone.	Arlesey, Beds.	Barrington, Cambs.	Hunstanton, Norfolk.	Speeton, Yorks.
Per cent. of coarse residue.	11·82	4·62	1·44	1·35	·31	·28	·14	·31
Per cent. of fine residue.	15·45	10·11	23·31	35·95	24·07	21·58	4·73	15·83
Total per cent. of residue	27·27	14·73	26·75	37·30	24·38	21·86	4·87	15·84

A second series may be taken from the foregoing table of samples between 20 feet and 45 feet above the base of this zone. Some remarkable differences occur here which must be considered in detail.

20 to 45 ft. above the Base of the Zone.	Mupe Bay 20ft. above base.	Isle of Wight ? 20ft. to 25ft above Base.	*Folkestone soft 20 above Base.	Folkestone 35ft above Base.	Arlesey 45ft above Base.	Hunstanton 6ft. below Tot.stone.	Speeton 15ft below the Grey Bed.
Per cent. of coarse residue.	3·27	·767	·47	·17	·20	·01	·013
Per cent of fine residue	16·02	39·03	27·41	21·96	45·99	3·02	5·038
Total per cent. of residue.	19·29	39·80	27·88	22·13	46·19	3·03	5·051

* Not included in the regular series.

The first, from Mupe Bay, as already noted, shows a decrease in the amount of coarse residue in that locality; but in the next, a specimen from the Isle of Wight, taken from Dr. Hume's Micro-Mineralogical Researches, which, judging from the description given, was obtained from 20 feet to 25 feet above the base of this zone, shows a decided increase of the fine material not only when compared with Mupe Bay, but also when compared with a specimen lower in the zone from another locality in the island (Compton Bay).

Dr. Hume also records the analysis of a specimen of chalk from Culver Cliff, Isle of Wight, which he refers to the zone of *Holaster subglobosus*. The specimen yielded a residue of 44·85 per cent. on treatment with the acid solution. From Dr. Hume's description of the horizon and the results of our own analyses of chalk of the zone of *Holaster subglobosus* at the Isle of Wight, we felt sure that this specimen came from the upper part of the beds which are now taken as the zone of *A. varians*, and we have included it in this division. Our surmise as to the horizon of this specimen proved to be correct, for, having had an opportunity of consulting Dr. Hume, he agrees that the chalk from which he took the specimen is part of that which we include in the lower zone. There is therefore a still greater increase in the amount of terrigenous material in the upper part of this zone in the Isle of Wight.

But such increase is by no means exceptional. At Arlesey the amount of clay 45 feet above the base is nearly double the amount in the basal specimen—viz., 46·19 per cent., compared with 24·38 per cent. Professor Judd records a residue of 50 per cent. from Chalk Marl of the Richmond boring.*

It is important to notice that this increase is not in the coarse particles, but chiefly in fine mud; so fine indeed is it at Arlesey that it is impossible to separate the minute mineral grains from the rest of the deposit, though in thin sections they are easily seen to be very numerous when the rock is viewed under the microscope. Though this high percentage of clay falls again at Arlesey towards the summit of the zone, it is even then large compared with any sample just above the base.

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* Quart. Journ. Geol. Soc., Vol. xlii. p. 435.

At Folkestone the percentage of coarse particles and fine mud seems to decrease progressively from the base to the summit of the zone, but the proportionate decrease of coarse particles is greater than that of the clay. This is shown in the three analyses quoted, and is confirmed by the examination of thin slices of the rock.

At Hunstanton the deposit is practically a pure chalk, the insoluble residue being only 3·03 per cent., but at Speeton the percentage of residue at this higher horizon shows an increase when compared with the Hunstanton specimen.

THE QUARTZIFEROUS LIMESTONES OF DEVONSHIRE.

ADDENDUM TO P. 274.

Microscopic Aspects.

The lowest and coarsest part of the deposit is unfit for slicing, but the higher part of No. 10 has been cut and is seen to be a sandy rock, consisting of large quartz-grains (mostly well rounded) and shell fragments of many kinds, with Foraminifera and a sprinkling of glauconite-grains, the whole cemented by clear crystalline calcite. Among Foraminifera *Textularia*, *Cristellaria*, *and Rotalia* are common, *Globigerina* is rare or absent. There are many pieces of sponges (? Calcisponges), a few spicules of Siliceous Sponges, and some fragments of Bryozoa.

The succeeding bed (No. 11) resembles the finer and more shelly portions of the bed below; it consists mainly of calcareous particles derived from various sources, with Foraminifera and Sponge-spicules, and many grains of quartz and glauconite, the latter being more frequent than in Bed 10. The whole is cemented by crystalline calcite. There are no Spheres.

The highest part of the *Am. Mantelli* zone (the No. 12 of Meyer) is a different rock, parts of it being a true chalk, not unlike an ordinary Chalk Marl. The matrix consists of fine amorphous, calcareous matter, through which are scattered many Spheres, a few shell fragments, with some Foraminifera and Sponge-spicules. It differs from Chalk Marl, however, in containing large quartz-grains, large grains of glauconite, and large shell-fragments, these often occurring all together in patches, which are, nevertheless, integral parts of the rock, and are not sharply marked off from the finer portions.

Bed 13 is a similar but less consolidated rock. The matrix is a chalk with spheres and small Foraminifera, but with fewer shell-fragments. It differs from 12 in being more crowded with large grains of quartz and glauconite, the former occurring in rounded, subangular and angular grains.

Dr. Hume examined a sample of the hard limestone west (? south) of Beer Harbour, and we believe this to have been taken from Bed 12. His other sample was from Bed 13, near Lyme Regis.

CHAPTER XXIII.

THE MICROGRAPHIC STRUCTURE OF THE BEDS FORMING THE ZONE OF HOLASTER SUBGLOBOSUS.

BY W. HILL.

D. THE TOTTERNHOE STONE.

The external appearance of this bed is that of a hard grey gritty chalk, usually containing small brown-black phosphatic nodules, and when examined with a hand lens is seen to be speckled with black points which are grains of glauconite. The stone occurs in lenticular beds of varying thickness, in which shell-fragments predominate, and which are separated in Bedfordshire, Hertfordshire, and Cambridgeshire, by layers of less shelly chalk.

Microscopic Aspect of Thin Sections.

When thin slices of the stone—which is most esteemed for building purposes, and is quarried for that purpose at Totternhoe (Bedfordshire) and Burwell (Cambridgeshire)—are examined under the microscope, the shell-fragments are seen to be evenly distributed and to have a uniform size. The greater part of them can be recognised as prisms of Inoceramus-shell, and they constitute at least 60 to 70 per cent. of the mass. The remainder consists of glauconitic and minute mineral grains, both exceptionally abundant compared with the Chalk above and below, and Foraminifera, amongst which forms of *Globigerina*, *Textularia*, and *Rotalina* can be recognised. The whole is compacted together in a matrix of amorphous material, but in some places, especially where shell-fragments are coarse, probably allowing an easy circulation of water, the matrix is chiefly granular crystalline calcite (see Pl. V.)

In the more northern counties the Totternhoe Stone, though thin, is well marked, and its general characters differ little from the stone at Totternhoe, except in the greater irregularity in the size of the shell-fragments and the gradual decrease of the sandy elements. Through Norfolk, Lincolnshire, and Yorkshire it preserves its character as a thin bed of shelly chalk, and at the final exposure in the Speeton Cliffs it can still be recognised, though apparently from the increase of amorphous material the bed may be again passing laterally to less shelly chalk.

Examination of the Washings.

Portions of the Totternhoe Stone from Arlesey in Bedfordshire and Heacham in Norfolk were washed in water and much of the finest material was thus removed; the remaining coarse particles were then examined. The material was difficult to separate, small masses of shelly particles being frequently cemented together by calcite.

In that from Arlesey the coarse shell-fragments consisted largely of prisms of Inoceramus, a few Echinoderm plates, and spines and short pieces of Bryozoa. Small fish teeth and scales were common, and ovoid and cylindrical coprolites numerous.

The Heacham specimen gave somewhat similar results. Inoceramus-prisms were very abundant, but there were also a good many flat shell-fragments the derivation of which was obscure. A few fragments of Bryozoa occurred, but no Echinoderm-plates or spines were noted, nor were fish teeth or coprolites so common as in the Arlesey specimen.

Foraminifera.—The following species were isolated from the washings and residues, and were identified by Mr. F. Chapman :—

——	Arlesey, Bedfsh.	Heacham, Norfolk.	Speeton, Yorks.
Rhizammina indivisa, *Brady*	–	x	x
Reophax nodulosa, *Brady*	–	–	x
Haplophragmium agglutinans (*d'Orb.*)	–	x	–
,, glomeratum, *Brady*	–	–	x
Ammodiscus incertus (*d'Orb.*)	–	x	x
,, charoides (*J. and P.*)	–	–	x
Trochammina sp.	–	–	x
Textularia trochus, *d'Orb.*	x	x	–
,, turris, *d'Orb.*	x	–	–
,, gramen, *d'Orb.*	–	x	–
Tritaxia tricarinata, *Reuss*	x	–	–
Verneuilina sp.	–	x	–
Lituola placentula, *Chap.*	–	–	x
Gaudryina pupoides, *d'Orb.*	x	x	x
,, rugosa, *d'Orb.*	–	–	x
,, sp., nov.	–	–	x
Bulimina brevis, *d'Orb.*	x	x	x
,, Presli, *Reuss*	x	x	x
,, affinis, *d'Orb.*	x	–	x
,, obtusa, *d'Orb.*	x	–	x
,, Orbignyi, *Reuss*	x	x	–
Lagena apiculata, *Reuss*	x	–	–
Nodosaria oligostegia, *Reuss*	–	x	–
Marginulina robusta, *Reuss*	–	x	–
Cristellaria Italica, *Defr.*	–	x	–
,, planiuscula, *Reuss*	x	–	–
,, cultrata (*Montf.*)	x	–	–
Globigerina cretacea, *d'Orb.*	x	x	–
Truncatulina lobatula (*W. and J.*)	–	–	x
,, Ungeriana (*d'Orb.*)	x	–	–
Anomalina ammonoides (*Reuss*)	x	x	–
,, complanata, *Reuss*	x	–	–
Glandulina cylindracea, *Reuss*	x	–	–

The change already noted in the zone of *A. varians* of the facies of the Microzoa in the north-west of Norfolk and northwards is reflected in the Totternhoe Stone.

Rhizammina, *Reophax*, *Haplophragmium*, *Ammodiscus*, and *Trochammina*, all represented in North-west Norfolk and Speeton, were not observed in the examination of the Arlesey specimen. The specimens of *Bulimina* and *Gaudryina* are, as usual, smaller in the north than in the south.

Ostracoda.—The valves of Ostracods were fairly numerous in the Arlesey specimen. The following were isolated from the washings, and were namedtby Mr. Chapman :—*Cythereis triplicata* (Roem.) and *C. ornamentissima* (Reuss), *Cytheridea perforata* (Roem.), and *Cytherella obovata* (J. and H.).

In the Totternhoe Stone of Heacham they were less numerous.

Examination of the Residues.

Detrital Minerals.—Besides quartz and mica no other minerals have been definitely recognised in the Totternhoe Stone; their proportion of the coarse residue is small, the sandy nature of the stone being due to comminuted shell-fragments and not to mineral grains. In size they do not exceed those of the over or underlying Chalk, though the Heacham specimen contained a few grains which were larger than usual.

Secondary Minerals.—*Glauconite.*—This mineral occurs plentifully in the Totternhoe Stone of Arlesey and Heacham. It is generally of a pale green colour; many of the grains are small and rounded, but there are also many in the form of foraminiferal casts.

Marcasite.—Bright brassy spherules and small irregular masses of this mineral occurred in the Arlesey specimen, accompanied by masses of iron oxide, possibly derived from the oxidisation of this material.

Tabulation of Results.

The appended table gives the results of the treatment with the acid solution of four specimens of the Chalk at this horizon :—

THE TOTTERNHOE STONE.

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Colour.	Detrital Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Secondary Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Foraminifera.	Estimated per cent.	Shell fragments and indeterminable particles.	
26	Beds. Arlesey	gr'ms. 80·03	82·01	6·72	11·27	17·99	Grey.	Quartz, Mica	3·	mm ·18	mm ·11	Glauconite, including green matter, Iron oxide	20· 6·	mm ·37	mm ·09	Bulimina, Textularia, Gaudryina.	76·	1	This residue consisted chiefly of the debris of Arenaceous foraminifera, glauconite and green matter. No spicules observed. (Shell-fragments, a few Spheres, and Foraminifera, &c., estimated at 65 per cent.)
27	*Totternhoe. "The Rag" just above the building stone.	80·00	86·79	5·08	8·13	13·21	—	Quartz, Mica	—	—	—	Glauconite	—	—	—	—			A large part of the glauconite is in the form of foraminiferal casts, its colour rather pale green; sponge-spicules rare. (Shell-fragments coarse and uneven, with Spheres and Foraminifera estimated at about 70 per cent.)
28	Norfolk. Heacham ..	60·894	92·67	·46	6·87	7·33	Grey.	Quartz	4·	·43	·15	Glauconite	75·	·48	—	Rhizammina Haplophragmium, Ammodiscus Bulimina, Gaudryina.	20·	—	The quartz is in rather large grains, many are well worn and have a yellowish stain. The glauconite is of a pale yellowish green colour, and large numbers of the grains are evidently formed in the chambers of foraminifera; many can be seen to be beautifully perfect casts of *Ammodiscus*, *Anomalina*, *Globigerina*, and others. (Shell-fragments, chiefly Inoceramus-prisms, with Foraminifera and a few Spheres estimated to form 65 per cent. of this rock.)
29	Yorkshire. The "Grey Bed" at Speeton.	84·414	95·18	·18	4·64	4·82	Grey.	Quartz, a few grains only.	—	·19	·12	Glauconite, Iron oxide	— 25·	·09	—	Rhizammina Reophax, Haplophragmium, Ammodiscus? Trochammina Lituola? Bulimina, Gaudryina.	70·	? 5·	The iron oxide was in 5 rather large masses, with pale brownish rind and darker interior. Several large flat fragments? silicified shell occurred. (Shell fragments, Foraminifera and Spheres about 40 per cent.)

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* From notes by Dr. Hume.

E. THE CHALK ABOVE THE TOTTERNHOE STONE.

Above the horizon of the Totternhoe Stone, which over a large area marks the division of the two lower zones of the chalk, the true chalk may be said to commence, and the broad definition of it as a white soft limestone soiling the fingers will apply to the rock over a large extent of country.

The chalk, however, is not yet quite a pure white except, perhaps, in the highest beds in some localities. In the south-east and south it is mainly white or whitish; in Wiltshire, Berkshire, Oxfordshire, Buckinghamshire, and Cambridgeshire, the lower part is greyish and the upper part white. In Norfolk the whole is whitish grey or white at the summit. This continues through Lincolnshire and Yorkshire, though in the two latter counties the colour is curiously varied by pink bands.

As a whole it appears as a firm blocky kind of chalk; in some cases where local circumstances have favoured induration by calcite there are beds of hard semicrystalline limestone. In Yorkshire most of the Lower Chalk is of a rough nodular character.

As before, the details may be given under the following heads:—

1. Microscopic Aspects.
2. Examination of the Washings.
3. Examination of the Residues.
4. Tabulation of Results.
5. Summary of Chemical Work.

Microscopic Aspects.

Devonshire and Dorset.—A large number of examples were obtained from the neighbourhood of Membury in Devonshire, and Cerne Abbas (North Dorset). In the lower part of this zone in the above named localities "spheres" form an important feature in the rock, and may be estimated to form from 20 per cent. to 40 per cent. of it; shell-fragments are never abundant, and form from 5 to 10 per cent. more. Mineral grains of small size occur in nearly all specimens, but their proportion is very small indeed. Minute grains of glauconite also occur.

About the middle of the zone and in the higher beds "spheres" are exceedingly numerous, forming in some instances 80 per cent. of the chalk. Shell-fragments are coarser but less abundant, and there is a decrease both in mineral and glauconitic grains, though both can be seen in nearly all samples.

At Mupe Bay, South Dorset, 20 feet below the Belemnite Marl (30) "spheres" constitute 70 per cent. of the rock, shell-fragments 5 per cent., while mineral grains are more numerous and far larger than in North Dorset specimens.

In none of the examples of this zone from Devon or Dorset do Foraminifera other than spheres play an important part; it is only here and there that a form which may be referred to *Globigerina* or to *Textularia* can be recognised.

Sponge-spicules are to be seen only in two or three specimens. In one from Furley, near Membury, there occur the same forms already alluded to in the Chalk Marl as possibly those of Radiolaria.

Isle of Wight.—Along the south coast specimens present the same peculiarities as those of the inland localities. The basal beds of the Isle of Wight contain a large proportion of shell-fragments and much glauconite, thus faintly echoing, as it were, the conditions of the Totternhoe Stone. In the higher parts amorphous calcareous matter predominates, shelly fragments occur sparingly, while "spheres" are scattered through the mass, with minute *Globigerina* and *Textularia.*

Kent, Dover.—The specimen from 70 feet below the Belemnite Marl (36) contains about 10 per cent. of finely divided shell-fragments and 10 per cent. more of "spheres" and minute *Globigerina* and *Textularia* and foraminiferal cells, the greater part of the rock being amorphous material, chiefly calcareous, but containing fine inorganic matter also. At 40 feet below this Marl the chalk is nearly all amorphous material with very few shell-fragments or "spheres," though the minute Foraminifera noted above are still in evidence. The sample from 6 feet below the Belemnite Marl (37) is very similar, containing even fewer foraminifera "spheres" or shell-fragments.

Wiltshire.—We have but few specimens from this zone from Wilts. One each from Scratchbury Hill, Arn Hill, and Clay Hill, all near Warminster, are evidently from nearly the same horizon, probably about that of the Totternhoe Stone, or at least the base of the zone. Shell-fragments and "spheres" are abundant, the former somewhat coarse, these, together with a few Foraminifera, forming about 50 per cent. of the deposit. Comparatively large grains of glauconite are common, and the mineral grains are larger and more abundant than in other specimens of chalk at a similar horizon except that from South Dorset. In two specimens from the upper part of the zone from Brimsdown, near Devizes, 30 feet and 15 feet below the Belemnite Marls the rock is chiefly amorphous material, with but few shell-fragments or "spheres," the latter being most abundant in the highest example. In both small mineral grains occur with a few of glauconite. This is the highest horizon at which mineral grains have been recognised in a section. As in Dorset, Foraminifera are not common.

Berkshire and Oxfordshire.—Judging from specimens from various horizons in this zone in Berkshire, the general appearance of the Chalk does not alter much. In the lower part of the zone it is shelly and full of "spheres," but it passes up to a rock consisting chiefly of amorphous matter. Both mineral grains and glauconite occur, and the former are more abundant than in chalk of the same horizon to the northward.

We have a good series from Crowmarsh (Oxfordshire). Immediately above the Totternhoe Stone the chalk resembles that from near Warminster, in the amount of shell-fragments and "spheres," but mineral and glauconitic grains are fewer in number, and the former smaller. About 20 feet higher shell-fragments decrease, while mineral grains and glauconite, though comparatively rare, are to be seen high in the zone. "Spheres" are common, hardly abundant, but Foraminifera increase decidedly, though as a rule the individuals are not large and the area occupied by their tests is relatively small. *Globigerina* and *Textularia* are the prominent forms. Still higher the chalk is chiefly amorphous material, recognisable particles rarely forming more than 10 per cent. of the rock, but just under the Belemnite Marl, shell-fragments, Foraminifera and "spheres" increase again.

Bucks., Beds., and Herts.—In these counties (*see* Analyses 38 and 39) the chalk of the zone of *Holaster subglobosus* varies but little in structure. The lower part, just above the Totternhoe Stone, contains many finely-divided shell-fragments, "spheres," with a few Foraminifera, but mineral grains cannot often be recognised more than 20 feet above the base, while grains of glauconite are rare. Above this the chalk chiefly consists of amorphous calcareous material, with few shell-fragments, Foraminifera, or "spheres." (See Plate V., Fig. 2.)

The general character of the zone is, however, not infrequently broken by seams of more shelly chalk, and occasionally by beds which have marked characters of their own. Thus at Chalkshire (South of Wendover) there is a bed of hard gritty chalk locally called the Rag, and again at Ivinghoe (46) and Sundon beds of similar character are exposed at the same horizon. The deposit consists largely of comminuted shell-fragments, coarser and more unevenly assorted than in the Totternhoe Stone, with but little fine material. Foraminifera are fairly common, but the abundance of fish teeth and scales, fragments of bone, and small ovoid coprolites give a marked character to the bed.

The larger calcareo-phosphatic green-coated nodules which abound in the Rag have a structure identical with that of the grey chalk. Most of the nodules seem pierced by boring Molluscs, and the holes are now filled usually with coarse shelly material of the Rag, but sometimes with fine amorphous material.

Analysis of the material of this bed (see page 317) does not show any very exceptional difference to the chalk of the zone in this locality, but there are more coarse particles, the percentage of these being higher than the average. They consist chiefly of lumps of green mud (see page 312), sand being in small proportion. The Foraminifera are of the usual type—*Rhizammina, Tritaxia, Bulimina* and *Gaudryina*. Of the last genus, however, there is a new species or variety.

Between Totternhoe and Royston the upper part of the zone contains more "spheres," and shell-fragments and just under the Belemnite Marl both become very numerous. A feature now in the upper part of the zone is the increase in the number of *Globigerina* and *Textularia*. Both are usually very small, and the relative number seen in each example varies, but they are decidedly more numerous as a whole than in the more western samples.

Cambridgeshire.—At Cherry Hinton the following sequence of examples was obtained, and may be compared as showing the general aspect of samples of this zone in the Midland counties, taken at measured distances below the Belemnite Marl.

80 feet.—" Spheres " estimated at 60 per cent.; shell-fragments not common; Foraminifera rare; one or two glauconitic grains; no minerals observed.

60 feet.—Fine shelly fragments, " spheres," and Foraminifera do not form more than 15 per cent. of the deposit; *Globigerinæ* present, mostly of minute size, but two or three larger ones.

45 feet.—" Spheres " about 20 per cent.; shell-fragments rare; no Foraminifera, glauconite, or quartz.

30 feet.—Almost entirely amorphous material; neither " spheres " nor shell-fragments; a few minute Foraminifera (*Globigerina* or *Textularia.*)

15 feet.—" Spheres " fairly common; a few shell-fragments, and minute Foraminifera; amorphous material 85 to 90 per cent.

6 feet.—Shell-fragments coarse, abundant; " spheres " common; many minute *Globigerina* and *Textularia;* a few large specimens of the first named genus; the recognisable ingredients forming about 35 per cent. of the rock.

Norfolk and Suffolk.—The conditions indicated by the Cherry Hinton series continue through these counties, but as one progresses towards North-west Norfolk there is a general increase of shell fragments, and large *Globigerinæ* become a more constant feature, though the chalk still consists largely of amorphous matter.

Lincolnshire.—Through this county the chalk contains a large proportion of coarse particles which can be recognised as shell, while in some specimens " spheres " and Foraminifera are fairly numerous. Examples from the quarries near Louth contain from 5 to 10 per cent. of shell-fragments; " spheres " are common, and these, with small *Textularia*, small and large *Globigerinæ*, and here and there a *Rotalina*, together make up from 10 to 15 per cent. more of the rock.

There seems to be no important difference in the structure of the pink bands which occur in the zone.

Yorkshire.—Throughout Yorkshire the character of the chalk continues much the same, though some examples contain a still larger percentage of shell-fragments and Foraminifera. For instance, a specimen of the pink band at Swinham contains at least 50 per cent. of recognisable shell-fragments and Foraminifera, the latter not being so much in evidence in this example. A specimen from Park Farm, Londesboro', also contains many shell-fragments. In the specimens from Speeton shell-fragments, foraminifera, and spheres form from 15 to 25 per cent. of the rock.

Examination of Washings.

Coarse Material.

Portions of several of the specimens obtained for chemical treatment were washed with water and the coarser organic remains which they contained were noted. As a whole they differ so little from those contained in the zone of *Am. varians* that detailed reference is hardly necessary. In no case was the chalk characterised by the occurrence of any organism in exceptional abundance.

As one may expect from the description of the sections, the quantity of coarse material obtained was usually small. Several attempts were made to separate the coarse material and to estimate its percentage to the amorphous matter, but repeated drying and washing failed to break up small hardened masses of chalk and the separation was never completed satisfactorily.

Shell-fragments.—The shell-fragments, as before, were chiefly prisms of Inoceramus, while here and there part of a *Pecten, Rhynchonella* or *Terebratula* occurred. In nearly all specimens minute spines referable to *Hemiaster* or *Pseudodiadema* were found. In that from Telegraph Hill, near Cerne, there were a number of spines of a kind not noted in any other locality. They somewhat resemble the fistulous spine of *Diadema* figured by Wright (plate xiv., fig. 2, c., British Fossil Cret. Echinodermata, *Palæont. Soc.*). Coprolites, Fish-teeth or scales were rare.

Sponge-spicules do not occur, with the exception of some glauconitic rods, and are not recorded from any locality. Fragments of Bryozoa occur less commonly than in the Chalk Marl.

Foraminifera.—The species isolated from the washings and residues of this zone, were identified by Mr. F. Chapman. They are distributed amongst thirty-three genera, as follows:—

Family.	Genera.	No. of species.	—
Miliolidæ -	Nubecularia - - -	1	New species.
	Spiroloculina - -	2	
	Miliolina - -	1	New species.
Astrorhizidæ -	Rhizammina - -	2	One new species.
Lituolidæ - -	Reophax - - -	1	
	Haplophragmium -	4	One new species.
	Placopsilina - -	1	
	Lituola - - -	1	
	Ammodiscus - -	4	
	Trochammina -	2	One new species.

Family.	Genera.	No. of Species.	—
Textulariidæ	Textularia	9	One new species.
	Verneuilina	2	
	Tritaxia	2	
	Spiroplecta	2	
	Gaudryina	5	One new species.
	Bulimina	9	
	Bolivina	1	
	Pleurostomella	2	One new species.
Lagenidæ	Lagena	2	
	Nodosaria	4	
	Frondicularia	2	
	Rhabdogonium	1	
	Marginulina	1	
	Vaginulina	2	
	Cristellaria	7	
	Polymorphina	1	
	Ramulina	2	
Globigerinidæ	Globigerina	3	
Rotaliidæ	Discorbina	1	
	Truncatulina	1	
	Anomalina	1	
	Pulvinulina	1	
	Rotalia	2	

The total number of species is 82, and of these fifty-eight occur in the Gault, sixteen do not occur in that deposit, and eight are new to science. The assemblage as a whole is very similar to that of the underlying zone, though it contains three genera not recorded in the latter, viz., *Placopsilina*, *Lituola* and *Pulvinulina;* on the other hand, no example of the genus *Flabellina* has been observed in this zone.

The difference in the Foraminifera found in the specimens from North-west Norfolk and north of the Wash, when compared with those from the same zone in the Midland and Southern Counties, is even more striking than in the zone of *Am. varians.* Thus in the acid residues (the northern chalk is too hard to wash) of five specimens from North-West Norfolk, Lincolnshire, and Yorkshire the families of Miliolidæ, Astrorhizidæ, and Lituolidæ are represented by six genera and twelve species, the majority occurring plentifully. In these five specimens *Ammodiscus incertus* and *Am. charoides* occurred in every one, *Ammodiscus gordialis* in three, and *Ammodiscus tenuis* in two; species of *Haplophragmium* occur in all, one of which is new and seems peculiar to the North: it occurred in three out of the five specimens. Two species of *Spiroloculina* occur only in North-west Norfolk and Yorkshire. *Reophax nodulosa* is another form especially characteristic of this northern chalk. Only one specimen of *Textularia* was isolated, and three species of *Bulimina*, none of them common. The

Gaudryina are represented by *Gaudryina pupoides* and *G. dispansa*, the former not very common; the latter with *Lituola placentula* were only found at Speeton. *Tritaxias* are absent. All the Foraminifera are of small size.

Turning now to the residues of nine specimens of this zone from Dorset, Kent, and Herts, we find the families of Miliolidæ, Astrorhizidæ, and Lituolidæ represented by five genera and only six species, and all of them are comparatively rare. The genus *Textularia* is represented by eight species, some very common; *Tritaxia* by two species, generally present; *Gaudryina* by three species, *Gaudryina pupoides* being very common; *Bulimina* by eight species, *Bulimina Presli* and *B. brevis* being abundant. With the exception of *Haplophragmium nonionoides* and one or two doubtful specimens, none of this genus were noted in this zone in the southern counties. Most of the species were large, bold forms, and differed in this respect very markedly from those of the north.

As in the zone of *Am. varians*, the families of the Lagenidæ, Globigerinidæ, and Rotaliidæ were very generally distributed throughout the softer chalk of this division, and were all found in specimens obtained from the southern, south-eastern, and south-western counties.

Of the Lagenidæ, *Cristellaria* was the most common, *Cristellaria gaultina* occurring generally, none of the others being of frequent occurrence. *Globigerina cretacea* occurred everywhere, the specimens large. Although *Globigerinæ* are among the most prominent forms recognisable in thin slices, their proportion to the mass of the rock is very small. Amongst the *Rotaliidæ*, *Anomalina ammonoides* was generally abundant.

Ostracoda.—Valves of Ostracods are not very common in this zone. The only ones isolated were *Bairdea subdeltoidea* (Muenst.), *Cytheris ornamentissimum* (Reuss), *Cythere koninckiana* (Bosquet), and *Cytherella Muensteri* (Roemer), all of which occur in the zone below.

Finest Material.

The amorphous calcareous material which constitutes so large a proportion of the upper part of the Grey Chalk differs from that of the Chalk Marl in being in a finer state of division; the larger part of it consists of minute calcitic particles which give no hint of their derivation. The larger definite calcitic crystals described on p. 291, are less common, and the fragments which can still be recognised as pieces of shell or portions of the tests of Foraminifera are less abundant than in the Chalk Marl. Minute Foraminifera, chiefly *Globigerina* and *Textularia*, are frequently very common in the finest part of the washings.

Crystalloids are abundant, but we have not been able to identify a coccolith. Rhabdoliths may be frequently seen. Fine inorganic matter is recognisable in the lower beds of this division, but decreases upwards, and its effects are lost in the upper part of the Grey Chalk.

Examination of the Residues.

Detrital Minerals.—The quantity of detrital minerals in the chalk of the zone of *Holaster subglobosus* is exceedingly small, but there is a sensible diminution in the coarse residues when the lower parts of the zone are compared with the highest beds. It is probable also, as Mr. Teall remarks, that if a sufficient quantity of chalk were treated with acid and enough residue obtained all the minerals found in the zone below would occur at this horizon. The grains of quartz, which, as usual, are most numerous, are angular, subangular, or rounded, some being more worn than others.

The lowest specimen from Mupe Bay again stands first both as to the quantity of the coarse residue and the dimensions of the grains, though the quantity is estimated at only ·12 per cent. of the material used. The largest grains measure ·55 mm. in the longest diameter, the average being ·14 mm. Dr. Hume* notes a single grain in the Grey Chalk of Culver Cliff, the length of which exceeded 1·5 mm.

Outside Dorset the maximum length of any grain recorded in the residues does not exceed ·3 mm. in the Chalk of the southern counties, though in Yorkshire they slightly exceed this, the largest measuring ·38 mm.

The residues from the Lower Chalk were submitted to Mr. Teall, who reports as follows:—

The foreign clastic material is of the same type as that already described from the Chloritic Marl. Quartz is the most abundant constituent, and is always present. One specimen, that from Mupe Bay, 20 ft. above the top of the Chloritic Marl, was examined in detail, and the following minerals were recognised:—Quartz, microcline, garnet, zircon, rutile, ilmenite, and tourmaline. Orthoclase and oligoclase are probably also present. There can be little doubt that if equal quantities of the other residues had been examined in the same way similar results would have been obtained.

In addition to the foreign clastic material idiomorphic pyrite occurs in the specimen 4 feet above the red chalk and 35 feet below the Belemnite Marl at Speeton—in the former as cubes, sometimes in combination with octahedra; in the latter as octahedra, sometimes modified by the cube. (J.J.H.T.)

Secondary Minerals.—Glauconite.—This is a rare mineral in the zone of *Holaster subglobosus*, though it can be recognised here and there in the thin sections of specimens obtained along the outcrop of the chalk between Wallingford and Devonshire as high as the

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* Chemical and Micro-Mineralogical Researches, p. 36.

Belemnite Marls, but in those obtained along the South Coast east of Portland, and in the Midlands north-east of Buckinghamshire, glauconite grains are of rare occurrence, especially in the higher parts of the zone, and are only seen in the residues when a quantity of chalk has been treated with acid. In the chalk of this zone from Lincolnshire and Yorkshire it is also rare. Dr. Hume notes it as infilling the tests of Foraminifera in the Isle of Wight, and a few rods, probably residuary sponge spicules, were found in the residue of a specimen from Cerne Abbas, Dorset. Glauconite, however, occurs in a specimen of bluish-grey chalk from Eastbourne, and abundantly in the "Rag" of Ivinghoe.

In both the samples last mentioned, and more sparingly in the Chloritic Marl and in the Chalk Marl, there are masses of amorphous green matter easily pulverised when dry, forming a tough cake if damp when subjected to pressure. In the residues it is seen to be porous, as though there had been included in its mass minute calcitic particles which had been dissolved out by the acid. Heated on platinum foil it turns to a red-brown like iron oxide. It is found associated with the glauconitic grains in the Totternhoe Stone of Arlesey (Bedfordshire) and Heacham, (Norfolk), and the amount of it equals, if not exceeds, that of the glauconite, while in the "Rag" of Ivinghoe it predominates. Like glauconite, it fills the tests of Foraminifera, forming casts, but it also occurs in irregular lumps or masses of comparatively large size, far larger than any glauconitic grain.

There may be some relation between this green amorphous matter and the Green Muds described in the report of Deep Sea Deposits of the *Challenger* Expedition.* "There is also," says Sir John Murray, "in these muds mixed with glauconite a greenish amorphous matter which in part at least appears, to be of organic origin, for it blackens on being heated on platinum foil leaving an ash coloured with oxide of iron. These muds and sands, are almost always developed along bold and exposed coasts where no very large rivers pour their detrital matters into the sea." The deposits in which this material occurs most abundantly are certainly free from much coarse sandy material, and do not compare in this respect with those sandy beds at the base of the chalk where glauconite occurs in the greatest profusion.

Marcasite and Iron Oxides.—No bright brassy nodules of Marcasite occur in any of the residues of this zone, though it is probable that small brown nodules and cylinders found in many residues may arise from the oxidisation of this material. Masses of porous ferruginous matter sometimes form a large part of the residues.

In order to see if any differences existed between the material of the isolated bluish-grey patches so frequently seen in the Lower chalk and the whiter rock which immediately surrounds such patches, the Rev. W. R. Andrews, at our request, kindly forwarded to us examples from Eastbourne.

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* Deep Sea Deposits. Report of the *Challenger* Expedition, p. 236.

The results of our examination show that the bluish-grey chalk contained a larger proportion both of fine and coarse residue than the whiter.

In the bluish-grey example 1·18 per cent. of coarse residue was separated from the clay (nearly half of this was the green matter described above), there were a very few glauconitic grains, the remainder was foraminiferal *débris* and sponge-spicules. In the whiter chalk only ·20 per cent. of coarse residue was separated, nine-tenths of which was foraminiferal *débris* with some sponge-spicules; the remainder consisted of small masses of porous iron oxide, with only one or two grains of glauconite. The Foraminifera isolated from the two samples were identical, and in neither were there free quartz-grains of any size.

The clay separated was rather dark grey in the bluish, and grey inclining to a brownish tint in the whiter chalk. While washing the latter a kind of heavy flocculent matter was observed, which settled quickly and doubtless carried with it some of those finer particles which would otherwise have remained with the coarse residue.

Thus, it seems, the chief difference in these two samples is the presence of green matter in the bluish-grey chalk and its absence in the whiter.

The difference in the weight of the fine residue is remarkable in a deposit otherwise resembling each other. Can it be that in the whiter chalk the green matter has become oxidized, and that the salts of iron so formed have been removed by percolating water?

Though the green matter seen in the coarse residue was in small lumps, yet it may be distributed through the chalk in particles too small for separation. We have, however, been unable to detect it.

Tabulation of Results.

Appended will be found a table of the results of the analysis of sixteen specimens of the chalk of this zone from various localities and horizons. We are indebted to Mr. H. B. Woodward, for sending the two specimens from the Isle of Wight, and to the Rev. W. R. Andrews for two samples from near Eastbourne. The remainder are of our own collecting:—

TABULATION OF RESULTS. ZONE OF HOLASTER SUBGLOBOSUS

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of fine Residue.	Total per cent. Residue.	Colour.	Detrital Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Secondary Minerals.	Estimated per cent.	Maximum size of grain.	Average size of grains.	Foraminifera.	Estimated per cent.	Shell fragments and indeterminable particles.	
30	South Dorset. Mupe Bay, 20ft. below the Belemnite Marl.	gr'ms. 56·400	88·65	·68	10·67	11·35	grey -	Quartz -	71·2	mm ·55	mm ·14	Glauconite, Iron oxide	19·7	mm ·41	mm ·17	Nubecularia, Miliolina, Tritaxia, Textularia, Spiroplecta, Bulimina, Gaudryina	8·8	·85	A fragment or two of *Hexactinellid* mesh occurred in this residue, and several pieces of silicified shell, besides a few *Inoceramus*-prisms (Spheres abundant, estimated to form 70 per cent. of the rock shell-fragments 5 per cent).
31	Mupe Bay, 3ft. below the Belemnite Marl.	69·340	91·04	·17	8·79	8·96	grey -	Quartz, mica -	10·7	·51	·14	Glauconite, and a few pieces of porous Iron oxide	17·3	·42	·15	Placopsilina, Tritaxia, Textularia, Spiroplecta, Gaudryina, Bulimina,	71·	—	This residue contained a small proportion of fine silicious matter. Amongst the glauconite grains were a few rod-like lengths.
32	North Dorset. Cerne Abbas, 60ft. below the Belemnite Marl.	54·555	89·99	·19	9·82	10·01	grey -	Quartz -	·5	·39	·10	Glauconite, and a few grains of Iron oxide	7· 2·	·21	·16	Textularia, Bulimina, Gaudryina, Spiroplecta,	85·	1·	Hexactinellid sponge-mesh is present in this residue. The silicified fragments of shell were flat pieces and *Inoceramus* prisms. Several, fragments of silicious network also occurred.
33	Cerne Abbas, 3ft, below the Belemnite Marl.	35·498	91 26	·04	8·70	8·74	grey -	Quartz, a few grains only -	—	·15	·06	Glauconite	—	·12	—	Rhizammina, Tritaxia, Textularia, Bulimina, Gaudryina, Spiroplecta	97·	—	Only a few grains of quartz, and one or two of glauconite Hexactinellid sponge-mesh occurred·
34	Isle of Wight. 76ft. below the Belemnite Marl. Culver Cliff.	90·814	92·78	·15	7·07	7·22	dark grey	Quartz -	10·	·27	·10	Marcasite	·20	—	—	Haplophragmium, Tritaxia, Spiroplecta, Bulimina, Gaudryina	70·	—	The Marcasite was in elongate cylindrical and irregular masses, and a few spherules and brown fragments of similar shape appeared to be this material oxidised.

35	30ft below the Belemnite Marl. Culver Cliff.	103·513	92·98	·18	6·84	7·02	grey -	Quartz -	·10	·31	·10	Green material, Marcasite, iron oxide.	25·	—	—	Rhizammina, Haplophragmium, Ammodiscus Textularia, Tritaxia, Gaudryina, Spiroplecta.	65·	—	Several trifid sponge-spicules occurred in the residue, the spicular walls either encrusted or replaced by limonite. There was also much oxidised Marcasite: This material had also infilled foraminiferal tests, several casts cf which were seen. There were also large grains of green matter, not crystalline glauconite. See p. 310.
36	Kent. Dover, 70ft. below the Belemnite Marl.	83·707	88.54	·12	11·34	11·46	Dark grey.	Quartz -	.12	·08	·05	Glauconite rare, Iron oxide	— 69.	·05	—	Ammodiscus, Bulimina, Gaudryina.	18·	1·	The iron oxide (? Oxidized marcasite) was in long cylindrical lengths, sometimes bent in irregular curves. Resinous grains common A few short rod-like lengths of Glauconite (Calcareous particles, spheres and foraminifera, estimated at about 20 per cent.).
37	6ft. below the Belemnite Marl.	62.214	93.39	·10	6·51	6·61	grey	Quartz -	.2	·10	·05	Iron oxide	50·	—	—	Miliolina, Haplophragmium, Tritaxia, Textularia, Gaudryina.	45·	—	About half the coarse residue consisted of iron oxide in red-brown irregularly shaped masses. Resinous globules fairly common, but no glauconite was observed. (A few shell-fragments consisting of *Inoceramus*-prisms, broken plates, spines, and ossicles of Echinoderms, with a few foraminifera, make not more than 10 per cent of the deposit.) A few ovoid coprolites occurred in washings.
·38	Herts. Hitchin, 55ft. below the Belemnite Marl.	52 714	90·81	·06	9·13	9·19	grey	Quartz (only a few grains).	—	·28	·05	Iron oxide (a few fragments).	—	—	—	Miliolina, Tritaxia, Textularia, Gaudryina, Bulimina.	—	—	The residue was practically all arenaceous foraminifera or their debris, only a few minute quartz grains occurred. (The shell-fragments chiefly Inoceramus-prisms with a few Echinoderm plates, spines, and ossicles estimated 18 per cent.)

TABULATION OF RESULTS. ZONE OF HOLASTER SUBGLOBOSUS—*Continued.*

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Colour.	Detrital Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Secondary Minerals.	Estimated per cent.	Maximum size of grains.	Average size of grains.	Foraminifera.	Estimated per cent.	Shell fragments and indeterminable particles.	
		gr'mes.								mm	mm			mm	mm				
39	Hitchin. 6ft. below the Belemnite Marls.	63·835	96·42	·02	3·56	3·58	Grey	Quartz -	—	·28	—	None -	—	—	—	Rhizammina, Ammodiscus, Gaudryina, Bulimina.	—	—	With the exception of a few quartz-grains the whole of this residue consisted of arenaceous foraminifera. (Calcareous particles, viz., spheres, *Inoceramus*-prisms, and Foraminifera about 10 per cent.)
40	Norfolk. Heacham, 25ft. above the Totternhoe Stone.	93·261	97·12	·04	2·84	2·88	Dark grey	Quartz and a few minute black grains ? Ilmenite.	—	·14	·10	None -	—	—	—	Rhizammina, Reophax. Haplophragmium, Ammodiscus, Trochammina, Textularia, Bulimina, Gaudryina.	—	—	A large part of the coarse residue consisted of small aggregations of siliceous matter stained a pale brownish, and appeared to be minute mineral grains cemented by iron oxide. (Shell fragments, spheres, and Foraminifera 20 per cent.)
41	Barret Ringstead, Hunstanton, 6ft. below Melbourn Rock.	73·464	95·78	·09	4·13	4·22	Dark grey	Quartz -	—	·27	·09	Iron oxide	10	—	—	All those in No. 40 with Spiroloculina.	—	—	The iron oxide was in pale yellowish brown cylinders and irregular masses. The remainder of the residue consisted of arenaceous foraminifera and their *débris*.
42	Lincolnshire. Louth, 3ft. below the Belemnite Marls.	73·573	98·311	·011	1·678	1·689	Rather pale grey	Quartz (a few grains)	—	·26	·10	—	—	—	—	Rhizammina, Reophax, Haplophragmium, Ammodiscus.	—	—	The tests of nearly all the arenaceous foraminifera were stained a bright orange yellow. (Shell fragments mostly small; 10 per cent. Foraminifera, consisting of a few *Globigerina*, *Textularia*, and here and there a *Rotalina* form about 10 per cent. Not many Spheres).

43	Yorkshire. Speeton, hard grey rough chalk, about 35ft. below the Belemnite Marls.	74·598	87·50	·26	12·24	12·50	Grey	Quartz -	1	·38	·15	Glauconite (rare), Marcasite	— 20	·24	—	Rhizammina, Reophax, Haplophragmium, Ammodiscus, Trochammina, Gaudryina, Bulimina, Pleurostomella.	75·0	—	The Marcasite was in bright brassy crystals. There were a few flat fragments of silicified shell and Inoceramus prisms.
44	Hard smooth chalk, 20ft. below the Belemnite Marls.	76·947	94·22	·16	5·62	5·78	Grey	Quartz -	—	·34	·11	Glauconite (rare), Marcasite	— 80	·22	—	Spiroloculina, Reophax, Haplophragmium, Ammodiscus, Trochammina, Gaudryina.	—	—	The Marcasite here was for the most part in octahedral crystals, separate, or in small aggregations. In colour reddish brown, with a dull metallic sheen.
45	Hard crystalline chalk, 3ft. below the Belemnite Marls.	80·352	98·19	·09	1·72	1·81	Pale grey	Quartz -	—	·28	·06	—	—	—	—	Reophax, Ammodiscus, Trochammina.	—	—	Chiefly the *débris* of arenaceous Foraminifera. Very few mineral grains; no glauconite or iron oxide observed.
46	Sussex. Eastbourne, Bluish grey chalk, zone H. subglobosus.	38·207	75·00	1·18	23·82	25·00	Grey	Quartz in minute grains	—	—	—	Green matter Glauconite a few grains	40·0	—	—	Tritaxia, Textularia, Bulimina, Gaudryina, Sponge-spicules, &c.	55·0 —	— 5·0	
	The white chalk, same locality and zone.	50·867	84·30	·20	15·50	15·70	Brownish Grey	Quartz in minute grains	—	—	—	Iron oxide Glauconite very few grains	12	—	—	As above Sponge-spicules, &c.	80·0	8·0	
48	The "Rag," Ivinghoe, Bedfordshire	86·948	93·29	·83	5·88	6·71	Grey	Quartz -	1	·46	21	Green material, Glauconite, Iron oxide	23 2·5 4·5	—	—	Rhizammina, Tritaxia, Gaudryina, Bulimina.	66·0	3·0	The coarse residue was chiefly the *débris* of arenaceous Foraminifera and green matter (see page 310).

Summary of Chemical Results.

One of the chief features observable in the series of analyses of specimens of this zone given below is the gradual approach to uniformity in the deposit throughout its range from the west of England to Hertfordshire, and it will be observed that the analyses do not show the marked differences which occur in the lower zone.

Specimens from 20ft to 70ft. below the zone of Bel. plena.	Mupe Bay. 20ft. below the Bel. Marls.	Cerne 60ft. below the Bel. Marls.	Isle of Wight 76ft. below the Bel. Marls.	Dover 70ft. below the Bel. Marls.	Hitchin 55ft. below the Bel. Marls.	Hunstanton 15ft. from base of zone.	Speeton (1), 15ft. above Grey Bed.	Speeton (2), 25ft. above Grey Bed.
Per cent. of coarse residue - -	·68	·19	·15	·12	·06	·04	·76	·16
Per cent. of fine residue - -	10·67	9·82	7·07	11·34	9·13	2·84	12·24	5·62
Total per cent. of residue - -	11·35	10·01	7·22	11·46	9·19	2·88	13·00	5·78

The Dover specimen contains the largest percentage of fine clay. In the Isle of Wight there must have been a rapid cessation of the influx of the clay noted in the underlying zone, the quantity decreasing to 7¼ per cent. Similar conditions, however, obtain in Hertfordshire. To the north-eastward of Hertfordshire the Chalk becomes still more pure, and at Hunstanton there is little difference between this zone and the one below it. The Speeton specimens again show an increase, and the lower one contains more fine mud than any of the others.

The percentage of coarse residue again shows progressive decrease from west to east. That of the South Dorset specimen still contains a larger percentage of free sand than any other, and both in this and the next above it sand-grains are conspicuously abundant, but at Dover and Hitchin the coarse residue is largely foraminiferal *débris*. The same remark applies to the Speeton specimens. The greater part of the coarse residues consist indeed of mineral particles, but they are the extremely minute grains which are selected by the arenaceous foraminifera for the formation of their tests and the *débris* of these usually forms the largest part of the coarse residue.

In the next series selected the specimens are all taken as nearly as possible to the same horizon, just a few feet beneath the Belemnite Marls, the summit of this zone.

Specimens within 6ft. of the Bel. Marls.	Mupe Bay.	Cerne.	Dover.	Hitchin, Herts.	Hunstanton, Norfolk.	Louth, Lincs.	Speeton, Yorks.
Per cent. of coarse residue.	·17	·19	·10	·02	·09	·011	·09
Per cent. of fine residue.	8·79	9·82	6·51	3·56	4·13	1·678	1·72
Total per cent. of residue.	9·96	10·01	6·61	3·58	4·22	1·689	1·81

These, as before, show a gradual decrease in the amount of residue from west to east, but a point to be noticed here is that the Hunstanton specimen contains a slight increase in the percentage of fine mud when compared with those from Hitchin, Hertfordshire, and Louth, Lincolnshire. The Belemnite Marls are absent in North-west Norfolk, and it is possible the fine mud which we shall see present in the next zone may have reached this district in sufficient quantities to affect the deposit, but not enough to form the marked marly bed which exists where the sub-zone of *Actinocamax plenus* is well developed. The specimen was taken about 6 feet below well-marked Melbourn Rock. At Cerne there is also a higher percentage of fine mud; in this locality inorganic matter is found in the chalk for some distance below the Melbourn Rock, and it is possible that this specimen is affected by the incoming of fine mud which reached its climax in the Marls above.

Taken as a whole, specimens of this zone show a gradual decrease of fine inorganic material when each locality is compared in vertical section.

F. THE BELEMNITE MARLS.

Macroscopic Aspects.

The appearance of the Belemnite Marls is everywhere that of a marly chalk, breaking into thin laminæ under the influence of weather. Though usually soft, in a few localities, notably at Louth in Lincolnshire, the marl is indurated by infiltrated calcite, and is somewhat hard.

The colour is most frequently grey with a greenish tinge, but at Dover (Kent) and at Brockham (Surrey) it is a pale yellowish grey; at South Cave (Yorkshire) the colour is grey with intercalated layers of almost black clay.

In the counties of Bedford, Hertford, and Cambridge, especially, but in other localities also, the Belemnite marls are separated into two beds by a hard, smooth, white rock, the character of which is very constant. It consists wholly of "spheres" and amorphous matter, foraminifera and shell-fragments being rare. This bed of hard white chalk appears to be broken up in some localities, and a nodular rock occupies its place. The nodules of this rock have the same structure of the hard white bed, the surrounding matrix being full of shell-fragments.

Microscopic Aspect.

The appearance of the Belemnite marls from various localities when viewed under the microscope in thin sections was as follows:—

A specimen from South Cave, Yorkshire (very dark bluish-grey in colour).—Fine amorphous matter predominates. It appears to be largely inorganic, and is full of opaque particles; minute mineral grains occur throughout. No foraminiferal cells or "spheres" occur, but there are a few small shell-fragments.

Lincolnshire, two miles west of Barton-on-Humber.—Chiefly amorphous matter, but more calcareous than the last; a few minute mineral grains can be seen, and several others of a bright green colour (probably glauconite) occur. Small calcareous particles, probably of shell, are sparingly scattered through the matrix, but there are no "spheres," and very few foraminiferal cells.

In Bedfordshire, Hertfordshire, and Cambridgeshire the marl is full of small particles of shell, foraminiferal cells, "spheres," a few larger *Globigerinæ* and here and there a *Textularia;* the relative amount of the recognisable organic ingredients varies greatly, the total varying from 30 to 80 per cent. For example—in the lower band at Pitstone, near Tring, about 60 per cent. of the Marl consists of "spheres," and cells, with a few larger Foraminifera and shell-fragments, "spheres" largely preponderating.

Near Luton the upper marl bed chiefly consists of amorphous, structureless material with few "spheres" or cells or larger *Globigerinæ,* but the mass is full of minute calcitic particles, probably shell, with a few larger fragments. At Cadwell, near Hitchin, where the hard white rock which occurs between the marly bands has been broken up and a nodular rock takes its place, the marl is very full of coarse shell-fragments, "spheres" and Foraminifera, shell-fragments predominating, the recognisable organic particles being from 70 to 80 per cent. of the Marl. At Litlington, near Royston, the marl has a similar shelly character.

A specimen from Winchester also consists largely of amorphous material. Mineral grains are rare. Foraminiferal cells, "spheres," minute *Globigerinæ,* with a few larger ones, are common, and are accompanied by many small shelly particles.

At Cerne, in Dorset, the material is chiefly amorphous, with small particles, probably derived from shells scattered sparingly throughout it, and here and there a coarser fragment; but few foraminiferal cells or "spheres." Mineral grains of minute size can be discerned throughout the mass.

In specimens from the south coast sections, the Isle of Wight, Eastbourne, and Dover, shelly particles are rarer, large foraminifera are more frequently seen, but cells and "spheres" are often extremely abundant, especially at Dover.

Examination of Washings.

Portions of most of the specimens which were treated with acid were also broken up in water and the finest part removed by levigation. As there is some difference in the results from this process in each specimen they will be considered separately.

South Cave.—After washing, the coarse particles of this specimen resolved themselves into thin, flat, flaky fragments, which remained intact after repeated wetting and drying. Foraminifera were very rare, all of those found were *Trochammina concava,* except a single specimen of *Pleurostomella alternans.* A few shell-fragments, chiefly *Inoceramus*-prisms, occurred, and one or two pieces apparently fish-scales. There were also two grains of glauconite; this mineral did not occur in the acid residue.

The finest material, though containing a large percentage of calcareous particles, contained also much inorganic matter. This was in the form of fine clay, but in it were many minute mineral particles too small for identification, but which give a decided reaction with polarised light. Minute opaque particles abounded, and there were also many minute opaque masses of irregular yet more or less globular form. Few of these exceed ·01 mm. in diameter, which precludes the idea that they may be "spheres" infilled with opaque material.

The calcareous particles were chiefly minute calcitic crystals giving no clue to their derivation. Larger particles, probably derived from shells or from Foraminifera and crystalloids, were far less abundant than in Southern specimens.

Cerne Abbas.—Foraminifera were fairly common in this specimen, but they were very small, and many minute *Textularia* and *Globigerina* came away with the finer parts of the marl when washed. None were isolated. The coarsest particles consisted chiefly of *Inoceramus*-prisms broken into small pieces and a few valves of *Ostracoda,* and one or two broken Echinoderm spines.

The finest material seemed to consist largely of calcitic particles, and crystalloids were common though hardly abundant. The inorganic material was an extremely fine clay with a few minute mineral particles.

Hitchin (lower band).—This contained a good many Foraminifera and Ostracod valves. There were also several minute and broken Echinoderm spines, and the ossicles of a starfish were also common. No large shell-fragments occurred amongst the coarser particles, the whole being much broken up. The amorphous matter consisted largely of minute calcitic particles, amongst which crystalloids were abundant.

Dover.—In the Dover marl Foraminifera are still more abundant, and several species of Ostracods occurred. The coarsest calcareous particles included plates and spines of Echinoderms, calcareous bodies of peculiar character which are probably ossicles of starfish (see page 510), a few flat shell-fragments, and portions of what appeared to be a *Rhynchonella* and *Inoceramus* prisms. Two or three minute fish-teeth, ovoid coprolites, and some pieces of scales were also found. Although there is considerable diversity in these coarser particles the actual amount of them is not large.

In the finest washings small Foraminifera were very common, consisting chiefly of small *Globigerina, Textularia* and "spheres"; crystalloids are also abundant.

The number of species of Foraminifera obtained from the residues by washing specimens of the Belemnite Marls from Dover and from the lower band from Hitchin, with others from the acid residues, is 34. The families and genera identified by Mr. F. Chapman are as follows :—

Family.	Genera.	No. of species.	—
Miliolidæ - -	Not represented.		
Astrorhizidæ -	Rhizammina - -	1	
Lituolidæ - -	Haplophragmium -	2	One new species.
	Ammodiscus - -	4	
	Trochammina -	1	
Textulariidæ - -	Textularia - -	3	
	Verneuilina - -	1	
	Gaudryina - -	2	
	Bulimina - -	4	
	Pleurostomella -	1	
Lagenidæ - -	Nodosaria - -	2	
	Frondicularia - -	1	A fragment.
	Flabellina - -	1	
	Vaginulina - -	1	
	Cristellaria - -	3	
	Polymorphina -	1	
Globigerinidæ -	Globigerina - -	1	
Rotaliidæ - -	Truncatulina - -	2	
	Anomalina - -	3	One new var.

At this horizon *Ammodiscus incertus*, and *A. charoides* are now of common occurrence both at Dover and Hitchin, the same forms also occurring in a specimen from Betchworth, Surrey. With this exception the assemblage as a whole is similar to that in the zones below, and in all probability if more specimens from a more extended area had been examined the similarity would be still greater.

The valves of the following Ostracods were isolated from the Dover specimen of this zone and identified by Mr. Chapman :—

Bairdia subdeltoidea (*Münst. sp.*)
Paracypris siliqua (*Jones*).
Bythocypris Brownei (*Jones*).
Cythereis (sp.).

Valves of Ostracoda also occurred in a washing of the lower marl-band at Hitchin and in the marl of Betchworth.

Examination of the Residues.

Detrital Minerals. The minerals which have at present been recognised in this zone are Quartz, Zircon, Tourmaline, and Orthoclase. Mr. Teall writes that the residue from the sample of the lower marl band at Hitchin, submitted to him for examination, contained many grains of the last-mentioned mineral.

Grains of Quartz measuring ·60 mm. occurred in the Cerne Abbas and South Cave examples, but the size seems exceptional, and only one or two grains in each case were so large as this, the remainder being small, not exceeding ·2 mm.

Secondary Minerals. – One or two grains of Glauconite occurred in the residue and washings of the Cerne Abbas specimen. Dr. Hume says that a few rods of glauconite occurred in the sample from Eastbourne, and a few grains in that from Swanage. Limonite and irregular masses of porous iron oxide were noted in the specimens from Eastbourne, Hitchin, and Dover.

Summary of Chemical Results.

The results of the treatment of six specimens of this zone with the acid solution are recorded in the annexed table. One of these is from Dr. Hume's Chemical and Micro-Mineralogical Researches, and two others are from notes kindly sent us by Dr. Hume.

It will be observed that there is in this zone a sudden increase in the amount of fine clay. This increase is most marked near the extreme south-west and north-east points of the area we are describing. At Swanage, Dorset, the amount of fine residue is 37·06 per cent.; at Cerne Abbas, Dorset, 30·33 per cent., or 20 per cent. more than that at the top of the underlying zone; at South Cave, Yorkshire, the increase is from 2 per cent. in the zone of *H. subglobosus* to 30·33 per cent. in this zone. There is, however, no corresponding increase of the coarser inorganic material.

RESIDUES.—SUB-ZONE OF ACTINOCAMAX PLENUS.

Number.	Locality.	General Composition.						Composition of the Coarse Residue.											Remarks.
		Amount of Material.	Per cent. Soluble in Acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Colour.	Detrital Minerals.	Estimated per cent.	Maximum size of Grains.	Average size of Grains	Secondary Minerals.	Estimated per cent.	Maximum size of Grains.	Average size of Grains.	Foraminifera.	Estimated per cent.	Shell fragments, and indeterminable particles.	
47.	Dorset. Cerne Abbas	gram's 18·655	68·81	·10	31·09	31·19	Dark grey	Quartz	5.	mm ·61	mm ·10	Glauconite (a few grains only), Iron oxide	—	mm ·25	mm ·13	None isolated	—	—	The coarse residue consisted largely of irregular aggregations of fine inorganic material. Many of these had a brownish tint and a few had a darker nucleus. Arenaceous Foraminifera practically absent, though a few fragments occurred. (In a washing from a specimen a little lower, there were a fair number of minute *Globigerina* and *Tertularia*, a few shell fragments and spheres.)
48.	* Isle of Purbeck. Swanage	79·02	62·47	·47	37·06	37·53	—	Quartz (a few grains)	—	·20	—	Glauconite Pyrites, Limonite	—	—	—	Ammodiscus, Haplophragmium			
49	† Sussex. Eastbourne	41·75	78·99	·08	20·9	21·00	—	Quartz, Zircon Tourmaline	—	—	—	Glauconite, Limonite	—	—	—	—	—	—	This residue contained very fine quartz, much limonite, a few rods of glauconite, and minute crystals of colourless tourmaline.
50.	* Kent. Dover	78·29	81·15	·044	18·80	18·85	—	—	—	—	—	—	—	—	—	‡Haplophragmium Ammodiscus, Gaudryina, Bulimina			
51.	Herts. Hitchin	72·374	80·89	·050	19·05	19·11	Pale ochreous grey	Quartz, Orthoclase	—	·18	·10	—	—	—	—	Rhizammina, Haplophragmium, Ammodiscus, Gaudryina, Bulimina	—	—	The quartz in this residue was in small evenly-sized grains. The major part of the residue consisted of the *débris* of Arenaceous Foraminifera.
52.	Yorkshire. South Cave	57·371	69·67	—	—	30·33	Very dark grey	Quartz, two large grains in washings	—	·60	—	Glauconite Iron oxide	—	—	—	Trochammina, Pleurostomella	—	—	The whole of the coarse residue of this specimen consisted of flat fragments of fine material which remained intact after repeated drying and heating. Two or three grains of glauconite.
53.	† Hitchin, Herts. Hard white rock between the marl bands	80·00	96·56	·015	3·421	3·436													

* Hume's Chemical and Micro-Mineralogical Researches, p. 68.

† From Notes by Dr. Hume.

‡ Our own Notes.

GENERAL SUMMARY OF THE COMPONENT MATERIALS OF THE LOWER CHALK.

The basal beds of the Lower Chalk vary considerably in their character. The arenaceous rock of Maiden Bradley differs widely from that of Folkestone, and this again from that of Shouldham in Norfolk. The basement bed in the Isle of Wight seems to present features intermediate between those of South Dorset and Folkestone, while that at Cerne, in North Dorset, has a character peculiar to itself.

Viewed as a whole they appear as deposits one would expect to find in a sea which gradually deepened from West to East. The quartziferous deposit of Maiden Bradley suggests a close approach to an adjacent shore line, while the abnormal thickness and sandy nature of the Chloritic Marl of Mupe Bay not only indicates the contiguity of land but probably also the action of strong currents.

It is remarkable to find within a mile of Mupe Bay—viz., at Lulworth, the features of the Chloritic Marl presenting so different an aspect; but even here, though the quantity of the coarser detrital minerals is small, the relative size of the grains is large.

Though the coarse detrital material decreases to the eastward, the fine mud increases. None of the Dorset specimens yield more than 15·8 per cent. of clay, while Bed 5 at Compton Bay, Isle of Wight, contained 19·9 per cent., and that at Shouldham in Norfolk 28 per cent. The Shouldham deposit seems to indicate that in Norfolk there was a closer approach to oceanic conditions, though this locality was still within reach of terrigenous material.

The amount of soluble material in the specimen of the basement bed at Cerne is greater than any of the others, but it will be seen in the sequel that this locality seems to be out of the reach of the mud-bearing currents, and that the Lower Chalk at all horizons contains less fine mud and less coarse material than specimens from South Dorset and the coast of Devonshire (Beer Bay).

The glauconitic sand of Folkestone is a greensand which may be compared with the greensands described in the Report of the *Challenger* Expedition.*

The salient features of these beds are so easily seen in the table (p. 272), that further comment is unnecessary.

In the chalk of the *Am. varians* zone it will be observed by reference to the table and general summary of the acid residues that fairly large quartz-grains continue to occur most abundantly in the specimens from the west of England.

In the arenaceous beds which represent this zone in Devonshire, the coarse mineral *débris* is unaccompanied by fine inorganic matter, and the matrix is practically a calcareous sand consisting of coarse particles, probably derived from the organisms which occur so commonly as fossils in these rocks, the interstices between the particles being filled with finer calcareous matter derived from the same source.

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* Deep Sea Deposits. *Challenger* Report, p. 239.

At Mupe Bay, South Dorset, quartz-sand forms a considerable part of the residue, but it is accompanied by a greater proportion of fine mud. At Cerne sand is also present in some quantity, but as usual the finest material is of a calcareous nature, and the amount soluble in acid is larger than at Mupe Bay.

Following the zone to the northward, along the outcrop of the Chalk through Wiltshire, Oxfordshire, and Berkshire, the aspect of the chalk when viewed in thin sections under the microscope suggests a slight current action, the rock being full of small, evenly-sized shell-fragments, and in these counties there is also an increase in the size of the mineral particles. Though fine inorganic material or fine mud is certainly present, the amount of it is not large.

Passing through Buckinghamshire into Bedfordshire analysis shows that there is a large accession of fine mud in the middle part of the zone, both the lower and higher parts containing a larger percentage of soluble material.

From the evidence both of thin sections and analysis it is clear that at the top of the zone the proportion of inorganic matter is everywhere decreasing and the rock becoming a purer chalk, though still containing much terrigenous material.

The fact seems now well established that to the north-east of Bedfordshire, through Norfolk and Suffolk, the rock passes laterally to a pure chalk. This continues through Lincolnshire and the greater part of Yorkshire, till at Speeton we again touch the fringe of shore-line deposits. It may be remarked that not until the purer chalk is reached do *Globigerinæ* frequently appear in the thin sections.

Returning to the south coast we find in the Isle of Wight an increase in the amount of fine mud in the middle part of this zone, as is the case in Bedfordshire; but at Folkestone there is a gradual decrease in the proportion both of coarse and fine inorganic matter upwards from the base of the zone.

In the Totternhoe Stone at the base of the overlying zone we again have evidence of the sweeping action of a current which has resulted in the sorting of calcareous and mineral particles, but there is no evidence of a mud-bearing stream. This sorting of the coarser particles and the sweeping away of the fine mud has resulted in the formation of a rock which, when viewed in a thin slice under the microscope, is seen to be a fine, calcareous sand, consisting chiefly of small even-sized fragments of shell with a small proportion of mineral grains.

In the succeeding beds, as we have already seen, the chief feature is the progressive decrease of terrigenous material and the gradual approach to comparative uniformity in the composition of the material throughout England. Features standing out strongly in the zone below are still, however, faintly repeated in this even to its very summit. Thus specimens from the south-west of England still show the strongest traces of the receding shores of the Cretaceous Sea, and, as before, the amount both of clay and coarse material diminishes to the east. The upper part of the zone, however, becomes nearly a pure chalk; nowhere does the amount of the residue exceed 10 per cent.

In the Belemnite Marls there is a sudden increase in the amount of fine clay. This increase is most marked at nearly the extreme south-west and north-east points of our area—viz., Cerne Abbas, Dorset, and South Yorkshire. At Cerne the residue increases from 10 per cent. at the summit of the underlying chalk to 31 per cent., and in South Yorks from 2 per cent. to 30 per cent.; at Swanage also the amount of the residue in the Marl is 37 per cent.

Although the Marls are well marked in Sussex, Kent and Herts, the amount of clayey material is less than at the above-mentioned localities—viz., at Dover the increase is from 6½ per cent. to 18¾ per cent.; at Hitchin (Herts) from 3½ per cent. to 19 per cent. We have no record of an analysis from the top of the Lower Chalk at Eastbourne, but the amount of residue in the Marls is 20 per cent.

At Eastbourne, Dover and Hitchin Microzoa are common; but in Yorkshire and Dorsetshire it was difficult to find either Foraminifera, Ostracods, or shell-fragments, though minute Foraminifera came away in the fine washings of the Dorset specimen.

Mr. Teall observes that the detrital mineral grains which have been observed in the Lower Chalk, are such as would arise from the decay of plutonic and metamorphic rocks, and it is extremely interesting to find them distributed over the whole floor of the Cretaceous Sea. In no case have minerals of volcanic origin been detected.

With regard to the *débris* of organisms which form very frequently so large a part of the deposit, *Inoceramus* shells play an important part. Prisms of the shell and sometimes larger fragments are found in every specimen, and many of the minutest particles are probably derived from their disintegration. Other shells add their quota to the mass of the rock; fragments of *Ostrea Plicatula, Pecten, Rhynchonella* and *Terebratula* have all been detected, though of less frequent occurrence.

Echinodermal plates and spines, though frequently recorded, are never a feature of the deposit, though the ossicles of star-fish occur near the top of the Lower Chalk rather commonly. Fragments of Bryozoa, though met with in all zones, are not numerous enough to suggest that any large accession to the calcareous mud was obtained by their decay.

Sponge spicules and the results of the decomposition of sponge structure play an important rôle locally, and we have seen in Dorset, Wilts, and Berks that these organisms have left marked evidences of their former existence.

It is difficult to say what proportion the Foraminifera contribute to the formation of the Lower Chalk. Those species which build up their tests with grains of sand are abundant in the lower beds, but become distinctly scarcer towards the summit of this division. Nothing is easier than to wash a sample of soft Chalk Marl and obtain many species and varieties not only of arenaceous Foraminifera, but also of those with porcellanous and vitreous tests. But sections of the rock never convey the idea of abundance, and none will compare in profusion of Foraminifera with those drawings of sections of Globigerina and other oozes published in the *Challenger* Report on Deep Sea Deposits. (Plates XI., XII., XIII.) In fact, many sections of the higher part of the *Holaster subglobosus* zone seem almost devoid of Foraminifera. In the finest part of the chalk pieces of broken foraminiferal tests are common, but they are far outnumbered by calcareous particles and crystals which give no clue to their derivation.

Taking all things into consideration, the amount of material which these minute forms contribute to the formation of the Lower Chalk cannot anywhere exceed 20 per cent., even if foraminiferal "cells" are included; it is usually less than this.

In this estimation, however, "spheres" are excluded. In some localities these are extremely abundant, and when estimated by the area they seem to occupy in a thin section, sometimes form more than half of it. It must be recollected, however, that they are all filled with amorphous (sometimes crystalline) material, and the actual amount which the cells themselves contribute to the deposit is smaller than appears.

The greater number of the species of Foraminifera which occur in this division of the Chalk range upward from the Gault; it should be stated, however, that these investigations have extended the upward range of many species. Of the 148 species and varieties identified in this division of the Chalk 102 are recorded in the Gault by Mr. Chapman*, twenty-seven are not recorded, and nineteen species and varieties are new to science.

On the whole in those parts of the Lower Chalk which are most purely calcareous, and where the quantity of recognisable particles exceeds that of the finer material, it may be said that particles of broken shells, and especially of Lamellibranch shells, are the chief constituent; next in relative quantity are the calcareous bodies which we have called "spheres," and thirdly Foraminifera; but at some horizons the spheres and Foraminifera combined form a larger proportion of the mass than the shell-fragments.

It should, however, be borne in mind, that though in the preceding pages prominence has been given to the definite grains and particles which can be separated from the matrix, yet in most samples of Lower Chalk the greater part of the mass consists of what has been classed as "finest material," and that it is only at certain horizons (as in the Totternhoe Stone) that the quantity of recognisable particles exceeds that of this fine material in bulk.

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* Foraminifera of the Gault of Folkestone. By F. Chapman. Journ. Roy. Micr. Soc. (1898).

LIST OF FORAMINIFERA FROM THE LOWER CHALK.

—	ent Beds.					Zone *Amm. Varians.*							Zone of *Hol. subglobosus.*					
	Cerne Abbas, Dorset.	Maiden Bradley Wilts.	Isle of Wight	Folkestone.	Shouldham, Norfolk.	Dorsetshire.	Isle of Wight.	Folkestone.	Bedfordshire.	Cambridgeshire.	Norfolk and Yorks.	Totternhoe Stone.	Dorsetshire.	Dover, Kent.	Hitchin, Herts.	N. W. Norfolk.	Lincs. and Yorks.	Bel. Marls.
Nubecularia sp. nov. (No. 1)	–	–	–	–	–	–	x	–	–	–	–	–	x	–	–	–	–	–
„ sp. nov. (No. 2)	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
Spiroloculina alveoliniformis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–
„ asperula, *Karrer*	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
„ papyracea, *Sherb., Burrows, and Bailey*	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–
„ tenuis, *Czjzek*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–
Miliolina venusta, (*Karrer*)	–	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–
„ sp. nov. (1), near alveoliniformis, *Brady*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	x	–	–	–
„ sp. nov. (2) between alveoliniformis and agglutinans (*d'Orb*)	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Rhizammina indivisa, *Brady*	–	–	–	–	–	–	–	x	x	–	x	x	–	x	–	x	x	x
„ sp. nov.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	x	–
Reophax cylindrica, *Chap.*	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
„ fusiformis, *Wills.*	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–
„ nodulosa, *Brady*	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–	x	–
„ scorpiurus, *Mont.*	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–
„ sp. nov.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
„ species	–	x	x	–	–	x	–	x	–	–	x	–	–	–	–	x	x	–
Haplophragmium acutidorsatum, *Hantken*	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
„ agglutinans, *d'Orb.*	–	–	–	–	–	–	x	–	–	–	–	x	–	–	–	–	–	–
„ ? emaciatum, *Brady*	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
„ glomeratum, *Brady*	–	–	–	–	x	x	–	–	x	–	x	x	–	–	–	–	x	–
„ irregulare, *Roemer*	–	x	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
„ nanum, *Brady*	–	—	–	–	–	–	–	x	–	–	–	–	–	–	–	x	x	–
„ nonioninoides, *Reuss*	–	x	–	–	–	–	–	x	–	x	x	–	?	–	–	–	–	–
„ sp. nov. (1)	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
„ sp. nov. (2)	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–
„ sp. nov. (3)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
„ species	–	–	–	–	–	–	x	x	–	x	x	–	–	–	–	–	–	–
Lituola placentula, *Chap.*	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–
Placopsilina cenomana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Ammodiscus incertus, (*d'Orb.*)	–	–	–	–	–	–	–	–	–	–	x	x	–	–	x	x	x	x
„ charoides, (*J. & P.*)	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	x	x	x
„ gordialis, (*J. & P.*)	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	x	x	x
„ tenuis, *Brady*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	x
„ sp. nov.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
„ species	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Trochammina concava, *Chap.*	–	–	–	–	–	–	–	x	–	–	x	–	–	–	–	x	–	x
„ sp. nov. (1)	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–
„ sp. nov. (2)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–
„ species	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–
Textularia anceps, *Reuss*	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–	–	–
„ agglutinans, *d'Orb.*	–	–	–	–	–	–	–	x	x	–	–	–	x	x	x	–	–	–
„ complanata, (*Reuss.*)	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–
„ conica, *d'Orb.*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
„ gramen, *d'Orb.*	–	–	–	–	–	–	–	x	x	x	–	x	x	x	–	–	–	x
„ minuta, *Berth*	–	x	x	–	–	x	–	c	x	x	–	–	–	–	x	–	–	–
„ prælonga, *Reuss*	–	–	–	–	–	x	x	x	x	–	–	–	x	–	–	–	–	–
„ sagittula, *Defr.*	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
„ trochus, *d'Orb*	–	x	x	–	x	x	–	x	x	–	x	x	x	x	–	–	–	x
„ turris, *d'Orb.*	–	x	x	–	–	x	–	x	x	x	–	x	x	x	x	–	–	x
„ distorted or sp. nov.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–
Verneuilina proquinqua, *Brady*	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
„ triquetra, *Münst.*	–	–	–	–	–	–	–	x	x	–	–	–	—	x	–	–	–	x
„ variabilis, *Brady*	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tritaxia pryramidata, *Reuss*	–	x	x	x	x	x	x	x	–	x	–	–	x	–	x	–	–	–
„ tricarinata, *Reuss*	x	x	x	–	–	x	x	x	x	x	–	x	x	x	–	–	–	–
Spiroplecta anceps, *Reuss*	x	x	–	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–
„ annectens, *P. & J.*	x	–	–	–	–	x	–	–	–	–	–	–	x	–	–	–	–	–
Gaudryina dispansa, sp. nov.	–	–	x	–	–	–	–	x	–	–	x	–	–	–	–	–	x	–
„ filiformis, *Berth*	x	–	–	–	–	x	–	x	x	x	x	–	–	x	–	x	–	–
„ new variety	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–
„ oxycona, *Reuss*	–	–	–	–	–	–	–	x	x	x	–	–	–	–	–	–	–	–

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* Those species marked c are those recorded by Mr. F. Chapman from the Chalk Marl in "Foraminifera of the Gault of Folkestone," Journ. Roy. Micro. Soc., 1898 page 40.

LIST OF FORAMINIFERA FROM THE LOWER CHALK—*continued.*

	Basement Beds.					Zone of *Amm. varians.*							Zone of *Hol. subglobosus.*					
	Cerne Abbas, Dorset.	Maiden Bradley, Wilts.	Isle of Wight.	Folkestone.	Shouldham.	Dorsetshire.	Isle of Wight.	Folkestone.	Bedfordshire.	Cambridgeshire.	Norfolk and Yorks.	Tottenhoe Stone.	Dorsetshire.	Dover, Kent.	Hitchin, Herts.	N.W. Norfolk.	Lincs. & Yorks.	Bel. Marls.
Gaudryina pupoides, *d'Orb.*	x	x	x	–	–	x	x	x	x	x	x	x	x	x	x	x	x	x
,, rugosa, *d'Orb.*	–	–	–	–	–	x	–	–	x	x	–	x	–	x	–	–	–	–
,, sp. nov. (1) depauperate form.	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–
,, sp. nov. (2)	–	–	–	–	–	–	–	–	–	–	x	..	–	–	–	–	–	–
Bulimina affinis, *d'Orb.*	–	x	–	–	–	–	–	x	x	–	x	x	x	–	x	x	x	x
,, brevis, *d'Orb.*	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
,, elegans, *d'Orb.*	–	–	–	–	–	x	–	–	x	–	–	–	–	–	–	–	–	–
,, Murchisoniana, *d'Orb*	–	–	–	–	–	–	–	x	x	x	–	–	x	x	–	–	–	x
,, obtusa, *d'Orb.*	x	x	x	–	x	–	x	x	x	x	x	x	x	x	x	–	x	x
,, Orbignyi, *Reuss*	x	–	–	x	–	–	–	–	x	x	–	x	x	x	x	–	–	–
,, obliqua, *Reuss*	–	–	–	–	x	–	–	x	–	–	x	–	–	–	–	–	–	–
,, ovulum, *Reuss*	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
,, Presli, *Reuss*	–	x	x	x	x	–	x	x	x	x	x	x	x	x	–	x	–	–
,, var. sabulosa, *Chap.*	x	–	–	–	–	–	x	–	x	–	x	–	x	–	–	–	–	–
,, pyrula, *d'Orb.*	–	–	–	–	–	–	–	–	x	x	x	–	–	–	–	–	–	–
,, trigona, new var.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–
,, variabilis, *d'Orb*	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–
Bolivina textularioides, *Reuss*	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	x	–	–
Pleurostomella alternans, *Schwager*	x	–	–	–	x	–	–	–	x	–	..	–	–	–	–	x	–	–
,, sp. nov.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Lagena apiculata, *Reuss*	–	–	–	–	–	–	–	x	x	–	–	x	–	x	–	–	–	–
,, hispida, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
,, sulcata, *W. & J.*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Glandulina cylindracea, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–
Nodosaria communis, *d'Orb.*	–	–	–	–	–	–	–	c	x	x	–	–	–	–	–	–	–	x
,, consobrina, *d'Orb.*	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–	–	x
,, farcimen, *Reuss* after Soldani.	–	–	–	–	–	–	–	x	x	x	–	–	–	x	–	–	–	–
,, humilis, *Roemer*	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–
,, orthopleura, *Reuss*	–	–	–	–	x	–	–	x	–	–	–	–	–	–	–	–	–	–
,, obscura, *Reuss*	–	–	–	–	–	–	–	c	x	–	–	–	–	–	–	–	–	–
,, oligostegia, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	x	–	x	–	–	–	–
,, perpusilla, *Chap.*	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–
,, plebia, *Reuss*	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
,, (D) paupercula, *Reuss.*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
,, prismatica, *Reuss*	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–	–	–
,, raristriata, *Chap.*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
,, soluta, *Reuss*	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–
,, (D) tenuicosta, *Reuss*	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
Frondicularia Archiaciana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–
,, Goldfussi, *Reuss*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
,, inversa, *Reuss*	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–
,, Parkeri, *Reuss*	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–	–	–
,, species	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Flabellina didyma, *Berth*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
,, rugosa, *d'Orb.*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Rhabdogonium tricarinatum, *d'Orb.*	–	–	–	–	–	–	–	–	x	x	–	–	x	x	–	–	–	–
,, var. acutiangulum, *Reuss*	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
,, excavatum, *Reuss.*	–	–	–	–	–	–	–	x	x	x	–	–	–	–	–	–	–	–
Marginulina glabra, *d'Orb.*	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–
,, Jonesii, *Reuss*	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–
,, Munieri, *Berth*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
,, robusta, *Reuss*	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–
,, striatocostata, *Reuss.*	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–	–	–	–
Vaginulina æquivoca, *Reuss*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
,, arguta, *Reuss*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	x	–	–	–
,, recta, *Reuss*	–	–	–	–	x	–	–	x	x	x	–	–	x	x	–	–	–	x
,, truncata, *Reuss*	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	–
Cristellaria Bronni, *Roemer*	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
,, convergens, *Born.*	–	–	–	–	–	–	–	–	x	x	–	–	x	–	–	–	–	–
,, cymboides, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
,, cultrata, *Montf*	–	–	–	–	–	–	–	c	x	–	–	x	–	–	x	x	–	x
,, exilis, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
,, gibba, *d'Orb.*	–	–	–	–	x	–	–	c	x	x	–	–	–	–	–	–	–	–

LIST OF FORAMINIFERA FROM THE LOWER CHALK—*continued.*

—	Basement Beds.					Zone *Amm. Varians.*						Totternhoe Stone.	Zone of *Hol. subglobosus.*					Bel. Marls.
	Cerne Abbas, Dorset.	Maiden Bradley, Wilts.	Isle of Wight.	Folkestone.	Shouldham, Norfolk.	Dorsetshire.	Isle of Wight.	Folkestone.	Bedfordshire.	Cambridgeshire.	Norfolk and Yorks.		Dorsetshire.	Dover, Kent.	Hitchin, Herts.	N. W. Norfolk.	Lincs. and Yorks.	
Cristellaria gaultina, *Berth* -	–	–	–	–	x	–	–	x	x	x	–	–	x	x	x	–	–	x
„ macrodiscus, *Reuss*	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–
„ italica, *Defr.* -	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–
„ planiuscula, *Reuss*	–	–	–	–	–	–	–	x	x	–	–	x	–	–	–	–	–	–
„ rotulata, (*Lam.*) -	x	–	x	–	–	–	–	x	–	–	–	–	–	–	x	–	–	–
„ secans, *Reuss* -	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
„ var angulosa, *Chap.*	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
„ sp. nov. - - -	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
Polymorphina var. acuplacenta, sp., *Jones and Chapman.*	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
„ communis, *d'Orb.*	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
„ fusiformis, *Roemer*	–	–	–	–	–	–	–	x	x	x	–	–	x	–	–	–	–	x
„ gibba, *d'Orb.* -	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
„ lactea, *W. & J.*	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–
Ramulina aculeata, *Wright* -	–	–	–	–	–	–	–	x	x	x	–	–	–	x	x	–	–	–
„ globulifera, *Brady* -	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	x	–	–
Globigerina cretacea, *d'Orb.* -	x	–	x	–	x	–	–	x	x	x	–	x	x	x	x	x	–	–
„ Linneana, *d'Orb.* -	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
„ marginata, *Reuss* -	x	x	–	–	–	–	–	x	–	–	–	–	x	–	x	–	–	x
Discorbina globularis (*d'Orb.*)	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
„ rosacea (*d'Orb*) -	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
Truncatulina Akneriana (*d'Orb*)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
„ lobatula, (*W. & J.*)	–	–	–	–	–	–	–	–	x	x	–	x	–	–	–	–	–	x
„ Ungeriana (*d'Orb*)	–	–	x	–	–	–	–	–	–	–	–	x	–	–	–	–	–	x
Annomalina ammonoides, (*Reuss.*)	x	x	x	x	x	–	–	x	x	x	–	x	x	x	x	x	–	x
„ complanata, *Reuss*	–	–	x	–	x	–	–	–	–	x	–	x	–	–	–	–	–	x
„ new variety- -	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Pulvinulina Karsteni, *Reuss* -	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Rotalia Soldanii, *d'Orb.* - -	–	x	x	–	x	–	–	x	x	x	–	–	x	–	–	–	–	–
„ var. nitida, *Reuss* -	–	x	–	–	–	–	–	x	–	–	–	–	–	x	x	–	–	–

CHAPTER XXIV.

CHEMICAL COMPOSITION OF THE LOWER CHALK.

The beds of the Lower Chalk vary considerably in chemical composition, as might be surmised from the obviously different lithological characters which they present at different horizons and at different localities.

The lowest beds, especially where they rest upon greensand, contain a large amount of sand and siliceous matter, and, roughly speaking, the proportion of such matter decreases upwards till in the higher and whiter part of the Lower Chalk there is not more than 9 or 10 per cent. of such matter.

The more marly beds, such as are generally known by the name of "Chalk Marl," usually contain from 66 to 80 per cent. of carbonate of lime, with sometimes a small quantity of carbonate of magnesia, but there is no regular upward increase in the proportion of carbonates, for the more purely calcareous beds alternate with the more argillaceous strata, and the former occasionally contain as much as 88 per cent. of carbonates.

In South Yorkshire, Lincolnshire, and North Norfolk the beds which represent the Chalk Marl are pure limestones containing from 85 to 95 per cent. of carbonates.

The upper part of the Lower Chalk, that is, the portion which is above the horizon of the Totternhoe Stone, does not vary nearly so much in composition, seldom having less than 88 per cent. or more than 94 per cent. of calcium carbonate, the average amount being apparently from 89 to 90 per cent.

In the Belemnite Marls at the top of the Lower Chalk we have a return to the conditions of the Chalk Marl, the proportion of calcium carbonate being reduced by admixture with from 10 to 20 per cent. of siliceous and argillaceous matter.

Analyses of Chalk Marls.

The following are analyses (A) of "grey marl from the lower part of the Chalk Marl," and (B) "of the harder part of the marl above the last" (A), both from near Farnham, Surrey.*

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* Paine and Way, Journ. Roy. Agric. Soc., Vol. xii.

	A.	B.
Soluble silica	2·16	2·11
Carbonic acid	29·96	36·73
Sulphuric acid	·21	·06
Phosphoric acid	·21	·05
Lime	41·52	49·16
Magnesia	·30	1·18
Potash and soda	1·90	1·47
Alumina	—	·20
Oxides of iron	2·20	1·74
Insoluble matter	21·35	7·26
	99·81	99·96

If all the carbonic acid found by these analyses is combined with lime the amount of carbonate of lime in A is 68·09 per cent., and in B 83·47 per cent., while in each case there is an excess of lime, amounting to between 2 and 3 per cent. beyond the amounts required to combine with the carbonic, phosphoric, and sulphuric acids. This excess was probably present as silicate of lime in combination with other silicates.

Both samples were probably taken from the lower part of the Lower Chalk, *i.e.*, from the zone of *Ammonites varians*, and, judging from the large quantity of insoluble matter in A, it must have come from near the base of that zone.

In Wiltshire and Berkshire certain beds in the lower and middle parts of the Lower Chalk, but probably all included in the zone of *Ammonites varians*, contain considerable amounts of colloid silica which is soluble in a boiling solution of caustic potash. In Wiltshire, moreover, siliceous nodules of a dull grey colour often occur in some of these siliceous chalks. Several analyses have been made by Professor J. B. Harrison (now the Government Chemist of British Guiana) from samples sent to him; two of these analyses have already been published and are reproduced below, A being a sample from near Collingbourne Kingston in Wiltshire, and B from a bed at Chilton in Berkshire:—

	A.	B.
Moisture	—	1·08
Combined water and organic matter	1·69	3·18
Colloid silica	38·69	19·08
Quartz	13·41	11·23
Silicates (clay and glauconite)	14·75	·47
Calcium carbonate	30·77	64.96
Calcium sulphate	·49	
	99·80	100·00

In the case of the Collingbourne material it will be seen that it can hardly be called a chalk, for two-thirds of it consist of siliceous matter, less than one-third being pure chalk or carbonate of lime. In the other sample the proportions are reversed, and this is a more usual composition, two other partial analyses of Wiltshire siliceous chalks showing totals of 34 and 35 per cent. of siliceous matter, 15 to 20 per cent. of it being soluble colloid silica.

A chalk-marl from Wiltshire analysed by Professor Voelcker in 1858* was evidently one of these siliceous marls, but he gives no locality, only stating that it "occurs in grey lumps at the foot of the Wiltshire Downs":—

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* Journ. of Bath and W. Eng. Soc., Ser. 2, Vol. vi., p. 240.

Finely divided silica, soluble in caustic potash	16·710
Insoluble siliceous matter	6·090
Alumina and oxide of iron	·780
Lime	40·757
Magnesia	·825
Potash and soda	traces
Phosphoric acid	·242
Sulphuric acid	1·546
Carbonic acid and loss	33·050
	100·000

Assuming that all the lime is in combination with the Phosphoric, Sulphuric, and Carbonic acids, and that the Magnesia is present as a carbonate, the following may be the mineralogical composition of this marl:—

Soluble silica (chiefly as free silica)	16·71
Silica (as quartz and clay)	6·09
Alumina and oxide of iron	·78
Carbonate of lime	70·35
Carbonate of magnesia	1·73
Sulphate of lime	2·62
Phosphate of lime	·52
Loss (by difference)	1·20
	100·00

Professor J. B. Harrison has also been kind enough to make partial analyses of two samples from the zone of *Am. varians* in Wiltshire A being a somewhat siliceous chalk from a quarry north-east of Clay Hill, near Warminster, and B a hard grey shelly chalk, somewhat resembling Totternhoe Stone, from the railway cutting at Upton Scudamore, in the same district. The results are as follow:—

	A.	B.
Water	·25	·04
Colloid silica	6·68	2·28
Quartz sand	6·42	3·47
Argillaceous matter (clay and glauconite)	19·07	6·22
Calcium carbonate (by difference)*	67·58	87·99
	100·00	100·00

Mr. Hill cut and examined a slice of B. (see p. 279) and found no globular colloid silica in it but many sponge-spicules, the walls of which still consist of the original colloid silica, so that it is evidently to these spicules that the 2·28 per cent. of colloid silica found by analysis is due. Grains of quartz and of glauconite are fairly numerous, and will account for the quartz and some of the argillaceous matter in the analysis. The sample A contains a small amount of globular colloid silica, as well as some sponge-spicules, sand and glauconite.

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* This will include magnesium carbonate, if any was present.

The following analyses of two samples of Chalk Marl from Arlesey, near Hitchin, are part of a series which have been kindly placed at our disposal by Mr. R. A. Berry. They are of special value because, like the analyses made by Professor J. B. Harrison, they are much more complete than ordinary commercial analyses and a special method has been devised to separate the quartz and the colloid silica from the clay and silicates. The carbonic acid was also determined in every case by direct weighing, and the amounts of calcium and magnesium carbonate calculated from it; the result being to show that a certain amount of the lime always remains, and this lime probably enters into the composition of the silicates. Of the two analyses given below, A is of the blue marl about 20 feet below the Totternhoe Stone (see p. 188), and B is of a grey marl about 6 feet below the same horizon :—

	A.	B.
Loss on ignition - - - - - -	1·30	·24
Calcium carbonate - - - -	50·02	66·45
„ phosphate - - - -	·73	·48
„ sulphate - - - -	·48	—
Magnesium carbonate - - -	1·55	·69
Lime - - - - - - -	3·39	2·83
Oxide of iron and alumina - -	1·07	2·08
Oxide of manganese - - - -	1·30	1·27
Clay - - - - - - - -	13·98	10·06
Quartz - - - - - - -	19·10	14·28
Colloid silica - - - - -	7·30	1·41
Alkalis and loss in analysis - -	—	·21
	100·22	100·00

Of the Chalk Marl of Cambridgeshire many analyses have been made in recent years for the numerous cement-making companies, and the two following series of analyses of successive beds at the same place have been kindly communicated by Mr. J. W. Knights, the County Analyst of Cambridgeshire :—

Analyses of Chalk Marls from Cherry Hinton.

	1.*	2.	3.	4.	5.	6.
Insoluble siliceous matter -	47·2	24·6	16·2	21·3	20·1	26·2
Carbonate of lime -	49·0	65·7	70·5	76·2	76·5	70·0
Alumina and oxide of iron	1·7	1·6	4·6	1·5	1·7	1·7
Magnesia and moisture - -	2·1	8·1	8·7	1·0	1·7	2·1
	100·0	100·0	100·0	100·0	100·0	100·0

The depths from the surface at which these samples were taken were as below, the coprolite bed lying at a depth of 24 feet :—

1.	2.	3.	4.	5.	6.
5 feet.	10 feet.	12 feet.	15 feet.	20 feet.	23 feet.

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* Some fine sand and gravel was mixed with this sample, accounting for the high proportion of insoluble matter.

Analyses of Chalk Marls from Barrington.

	1.	2.	3.	4.	5.	6.
Insoluble siliceous matter -	14·10	18·10	19·40	21·60	24·60	33·00
Carbonate of lime - -	83·20	78·90	77·24	74·50	71·50	62·20
Alumina and oxide of iron	1·70	1·60	2·10	2·10	2·30	2·80
Magnesia and moisture -	1·00	1·50	1·26	1·80	1·60	2·00
	100·00	100·00	100·00	100·00	100·00	100·00

No. 1 was taken at 4 feet from the surface.
No. 2 ,, 6 ,, ,,
No. 3 ,, 7 ,, ,,
No. 4 ,, 16 ,, ,,
No. 5 ,, from the bottom of the cement material.
No. 6 ,, from the layer overlying the coprolites.

The Marl at Cherry Hinton seems to have been worked under a bed of gravel and sand, and the infiltration of sandy material from this seems to have extended as deep as 10 feet from the surface. At 12 feet, however, we seem to have a pure marl containing 16 per cent. of siliceous matter, and the proportion of this increases downward till it amounts to 26 per cent.

The other series from Barrington shows a regular increase of siliceous matter from 14 to 33 per cent., with a corresponding decrease of calcareous material from 83 to 62 per cent., the lowest sample being evidently taken from the glauconitic marl which overlies the "coprolite bed."

Mr. Knights, however, informs me that the relative proportions of calcareous and siliceous material are not always so regularly distributed as in this case, even at Barrington itself, and that so far as the carbonate of lime is concerned the proportion varies in an uncertain and irregular manner. This is illustrated by a series of samples taken from the face of a trench at Barrington which Mr. Knights tested for carbonate of lime only with the following results:—

First Series.		*Second Series.*	
Depth from surface.	Proportion of $CaCO_3$.	Depth from surface.	Proportions of $CaCO_3$.
Feet.		Feet.	
3	67·5	1	79·0
5	61·5	3	74·5
7	74·0	5	73·0
9	84	7	85·5
11	70	9	88·0
13	72	11	68·0
15	76	13	67·5
17	62	15	74·0

The following are three more detailed analyses of Chalk Marls from Cambridgeshire, the first two having been made and communicated by Mr. J. W. Knights, and the third by Mr. H. Bassett (communicated by Mr. G. P. Gildea). The sample No. 1 was from near Cambridge, No. 2 from Poplar Hall Horningsey, and No. 3 from the late Mr. Colchester's cement works at Hauxton.

	No. 1.	No. 2.	No. 3.
Insoluble siliceous matter - - -	16·6	11·98	22·20
Carbonate of lime - - - - - -	69·0	84·41	72·18
Carbonate of magnesia - - - -	1·8	1·11	·75
Sulphate of lime - - - - - -	—	—	·29
Alumina - - - - - - -	1·0	1·49	2·50
Oxide of iron - - - - - -	2·7		
Alkali and traces of organic matter -	2·3	1·01	2·08
Moisture - - - - - - -	6·6	—	
	100·0	100·00	100·00

It should be notified that the first sample was analysed while still moist, and that if this moisture is allowed for, so as to compare with the other analyses, the proportion of carbonate of lime will become 73·87 per cent.

The following analyses have been made of the lowest beds of the Lower Chalk in North-west Norfolk and Lincolnshire, where these beds have the same lithological characters.

A and B were samples of the basement bed ("Sponge-Bed") at Hunstanton (A being from the very base) and were analysed by Dr. J. W. Johnstone. They are quoted from a paper by Professor T. McK. Hughes in Quart. Journ. Geol. Soc., vol. xl. p. 278.

C, D, and E were samples of the *Inoceramus*-Bed (see p. 283), C being from near Gayton in Norfolk, D from Hunstanton, and E from Gaumer Hill in Lincolnshire. C and D were analysed by Dr. W. Johnstone (see Proc. Norwich Geol. Soc., Vol. i., Part viii. p. 238 (1884), and Quart. Journ. Geol. Soc., Vol. xliii. p. 587). E was analysed by Mr. M. Staniland (see the Geology of East Lincolnshire, Mem. Geol. Surv. (1887), p. 33).

	Sponge-Bed.		Inoceramus-Bed.		
	A.	B.	C.	D.	E.
Moisture and organic matter - - -	trace	trace	1·112	1·40	·56
Carbonic acid - -	41·45	42·29	38·650	40·54	41·71
Phosphoric acid - -	·27	·29	2·522	·16	not estimated.
Sulphuric acid - -	trace	trace	·663	·09	
Lime - - - - -	52·05	53·23	47·250	51·50	52·44
Alumina - - -	trace	·35	trace	·35	—
Peroxide of iron (Fe_2O_3)	·63	·32	—	·50	1·50
Ferrous oxide (FeO) -	—	—	1·255	—	—
Manganese - -	—	trace	trace	·47	—
Magnesia - - -	·77	·75	·601	·25	·70
Sodium chloride -	—	trace	·058	·75	—
Insoluble residue -	5·02	3·17	7·554	3·38	3·01
	100·19	100·40	99·665	99·39	99·92

If the magnesia is present as a carbonate in all these samples, the carbonates of lime and magnesia in each are probably as follows :—

	A.	B.	C.	D.	E.
Carbonate of lime - -	92·29	94·25	79·84	91·61	93·04
Carbonate of magnesia -	1·61	1·57	1·26	·52	1·47

The sample of the Inoceramus-bed from near Gayton (C), is remarkable for containing so much phosphoric anhydride, equivalent to 5·5 per cent. of calcium phosphate. The amount of calcium carbonate would seem to be only 79·84 per cent., but there are some difficulties in reconstructing the mineral composition of the rock from this analysis.

In the case of C Dr. Johnstone also made a further analysis of the insoluble portion with the following results :

Insoluble part of C.

Silica - - - - - - - - -	5·547
Alumina - - - - - - - -	·900
Ferric oxide - - - - - - - -	·560
Calcium oxide - - - - - - -	·107
Magnesium oxide - - - - - - -	trace
Phosphoric acid - - - - - - -	trace
Organic matter - - - - - -	·440
	7·554

This appears to indicate that the greater part of the insoluble residue is fine quartz sand, with some clay and a little organic matter.

The following are three analyses of samples from the Lower Chalk of Speeton, made for Mr. W. Hill by Mr. J. W. Knights, of Cambridge.* The first (A) was a bluish-grey chalk taken about 6 feet above the top of the Red Chalk (Selbornian); B was taken near the top of Bed 3 where it is pink (*i.e.*, about 36 feet above the Selbornian). C is a whitish chalk from Bed 7, about 12 feet below the Belemnite marl.

	A.	B.	C.
Insoluble siliceous matter - - - -	12·40	5·40	6·00
Carbonate of lime - - - - -	82·40	92·80	89·80
Carbonate of magnesia - - - -	1·80	·75	1·66
Oxide of iron and alumina - - - -	1·40	·80	1·00
Undetermined matter - - - - -	2·00	·25	1·54
	100·00	100·00	100·00

It will be noticed that all these beds contain rather a large amount of siliceous matter, which is probably chiefly in the form of clay; this is especially large in the lowest bed, which in this respect presents a great contrast to the whitish limestone at the base of the Chalk along the western outcrop in the Wolds of Yorkshire and Lincolnshire.

It is somewhat remarkable that the pink chalk (B) should contain a rather larger amount of calcareous material (93·55 per cent.) than the whitish chalk from a much higher horizon (C), which has only 91·46 per cent.

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* See Quart. Journ. Geol. Soc., Vol. xliv. p. 358 (1888).

Analyses of the Totternhoe Stone and the Chalk above it.

Very few analyses appear to have been made of the Totternhoe Stone. An old one, of the stone quarried at Totternhoe, is quoted by Mr. Whitaker,* and states that "100 grains of the dried stone were found to contain . . . carbonate of lime 72, silex (in very fine white sand) 21, Alumina 7." This, however, does not read like an accurate analysis.

An analysis of a sample of the Burwell stone was made for the Geological Survey in 1880 by Dr. Frankland, and this is given below (A), quoted from the memoir on the Geology of Cambridge. A sample of the "grey bed" in Lincolnshire was analysed by Mr. J. W. Knights, of Cambridge, for Mr. Hill, in 1888.†

	A.	B.
Moisture at 100deg. (undetermined matter in B) -	·66	2·85
Insoluble residue (silica and silicates) - - - -	11·02	7·40
Carbonate of lime - - - - - - - -	85·91	86·40
Carbonate of magnesia - - - - - -	trace	2·15
Alumina - - - - - - - - -	·53	1·20
Peroxide of iron - - - - - - - -	·68	
	98·80	100·00

The insoluble residue in A was found by Dr. Frankland to have the following composition:—

Silica - - - - - - - - -	8·5
Alumina - - - - - - - -	·32
Protoxide of iron - - - - - - -	1·19
Lime - - - - - - - - -	·28
Magnesia - - - - - - - -	·29
Organic matter - - - - - - -	·44
	11·02

The following analyses are two of the series analysed by Mr. R. A. Berry (already mentioned); A is of the Totternhoe Stone at Arlesey near Hitchin, B, is of the highest part of the Lower Chalk just below the Belemnite Marl near Hitchin:—

	A	B
Loss on ignition - - - - - -	1·23	1·17
Calcium carbonate - - - - -	79·11	85·7
„ phosphate - - - - -	3·82	·76
„ sulphate - - - - -	·61	—
Magnesium carbonate - - - - -	·46	1·41
Lime - - - - - - - - -	1·71	1·61
Oxide of iron and alumina - - - -	4·11	·66
Oxide of manganese - - - - -	—	·32
Clay - - - - - - - - -	3·03	3·24
Quartz - - - - - - - -	4·72	3·11
Colloid silica - - - - - - -	1·02	1·81
Alkalis and loss in analysis - - - -	·18	·21
	100·00	100·00

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* Mem. Geol. Survey, Vol. iv. p. 41 (1872).

† Quart. Journ. Geol. Soc., Vol. xliv. p. 359.

The following are analyses of two specimens from the upper part of the Lower Chalk in Wilts and Dorset. Our thanks are due to Professor J. B. Harrison, of Georgetown, British Guiana, for making these analyses from samples sent over to him, and they exhibit the mineralogical composition of the material more completely than any others except Mr. Berry's, because his method of analysis secured complete separation of the several siliceous ingredients. Under the head of clay is included the combined silica existing in the form of silicates, with the associated alumina, peroxide of iron, oxide of manganese alkalis and magnesia.

No. 1 is a greyish chalk taken from about 20 feet below the Melbourn Rock in a quarry on Brimsdown, south-west of Warminster No. 2 is from a quarry at Belchalwell, Dorset, and from about 50 feet below the Melbourn Rock :—

	1.	2.
Moisture - - - - - - - -	·90	·20
Quartz - - - - - - - -	3·50	2·20
Clay (silicates) - - - - - -	4·95	6·00
Colloid silica - - - - - - -	1·15	2·95
Carbonates of lime and magnesia - - -	89·50	88·65
	100·00	100·00

It will be noticed that an appreciable amount of fine quartz sand is found in these samples by Professor Harrison, and this agrees with the results of Mr. Hill's chemical researches into the composition of samples from similar horizons in these counties (see p. 314).

Mr. Whitaker places at my disposal the following analyses of four samples of grey chalk (from two pits at Halling), lent by Formby's Cement Works Company, analysed by H. Faija, November, 1883, and communicated by Mr. J. H. Wood (of the Company).

	1. Top Old Grey Pit.	2. Bottom Old Grey Pit.	3. Top New Grey Pit.	4. Bottom New Grey Pit.
Moisture - - - - -	8·8	9·5	4·5	9·09
The Dried Residue contained :				
Carbonate of lime - - -	88·3	89·65	90·35	90·04
Silica - - - - - -	6·7	5·55	5·75	6·825
Alumina, with traces of iron -	5·	4·65	3·65	2·725
	100	99·85	99·75	99·95
Amount of quartz-sand - -	·15	·25	·20	·175

The following are two analyses of grey chalks from Kent. The first is stated to have been " a specimen from the base of the Grey Chalk at Folkestone," but it is not stated what bed was taken as the base of the " Grey Chalk," and as the analysis shows a very high proportion of calcium carbonate, it probably came from a high part of the Lower Chalk. The analysis was made by Mr. D. Forbes.[*] The second is an analysis of grey chalk from Snodland, quoted by Mr. J. L. Spoor.[†]

	1.	2.
Insoluble siliceous matter - - - -	3·61	6·84
Calcium carbonate - - - - - -	94·09	87·35
Magnesium carbonate - - - - -	·31	—
Alumina - - - - - - -	—	1·14
Oxides of iron - - - - - -	—	·38
Alkalis - - - - - - -	—	4·29
Sodium chloride - - - - - -	1·29	—
Water - - - - - - - -	·70	—
	100·00	100·00

It will be seen that the quantity of free quartz in these samples is very small, and that the greater part of the silica must be in combination with the Alumina as clay.

Of the beds forming the zone of *Offaster sphæricus* in Lincolnshire four analyses have been made and are given below. They include two of pink chalk (from the lower and the upper band) one of yellow chalk and one of a hard grey chalk occurring between the two pink bands. All the samples came from Louth, and were published in the Survey Memoir on East Lincolnshire. The first three analyses were made by Mr. Meaburn Stainland in the Laboratory of the School of Mines, London, and the fourth by Mr. Grant Wilson at Edinburgh.

	Lower Pink Band.	Upper Pink Band.	Yellow Chalk in Upper Pink Band.	Hard Grey Chalk.
Insoluble Portion.				
Silica - - - - - -	10·80	2·10	4·96	5·26
Alumina and peroxide of iron	1·10			1·57
Loss on ignition - - -	—	—	—	1·19
Soluble Portion.				
Lime - - - - - -	45·91	53·62	51·72	48·89
Carbonic acid - - -	36·51	42·86	40·91	38·51
Phosphoric acid - - -	trace	trace	—	·29
Magnesia - - - - -	·71	·36	·92	·73
Alumina - - - - -	1·35	—	trace	·31
Peroxide of iron - - -	1·03	·35	1·05	1·10[‡]
Oxide of manganese - - -	—	—	—	·15
Water - - - - -	1·92	·75	1·20	1·64
	99·33	100·04	100·76	99·64

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[*] See Quart. Journ. Geol. Soc., Vol. xxvii. p. xlix.

[†] Official Local Guide, Industr. Sec. (1889), p. 215.

[‡] Stated to be protoxide of iron.

The carbonates in these samples, as calculated from the amounts of carbonic acid, appear to be as follows:—

	Lower Pink Band.	Upper Pink Band.	Yellow Chalk in Upper Pink Band.	Hard Grey Chalk.
Carbonate of lime - - -	81·96	96·47	90·68	85·68
Carbonate of magnesia - -	1·48	·75	1·93	1·53

Several analyses of the marls of the zone of *Actinocamax plenus* have been made for the Geological Survey and others. The following are four of these:—No. 1 is from the Geology of Cambridge p. 55 (Mem. Geol. Survey), erroneously referred to the Melbourn Rock; the specimen was a yellowish marly chalk from the upper part of the zone near Harston, and was analysed by Dr. Frankland, F.R.S. No. 2 was a purple marl from a pit south-east of Gayton-le-Wold, in Lincolnshire, analysed by Mr. M. Staniland, F.G.S. No. 3 is a purple marl from Louth, analysed by Mr. Grant Wilson. No. 4 is from the dark bluish-grey marl exposed in the railway cutting east of South Cave, Yorkshire, and was analysed by Mr. J. W. Knights for Mr. W. Hill.

	1.	2.	3.	4.
Insoluble Portion.				
Silica - - - - - -	6·44	6·62	14·46	17·80
Alumina and peroxide of iron -	·92	2·18	5·44	
Lime and magnesia - - -	—	·52	1·04	
Soluble Portion.				
Carbonate of lime - - -	87·66	86·25	61·97	66·20
Carbonate of magnesia - -	3·44.	·94	5·48	6·20
Chloride of sodium - - -	·36	—	—	—
Alumina - - - - - -	1·51	1·35	·65	1·20
Oxides of iron - - - -		—	2·33	
Oxide of manganese - - -	—	—	3·20	
Water and organic matter -	—	1·62	5·10	8·60
	100·35	99·48	99·67	100·00

The following analyses are three more of those made and communicated by Mr. R. A. Berry, and are interesting as showing the composition of the grey marl and white chalk which form the Belemnite Beds in Bedfordshire. A is of the lower marl band near Hitchin, B of the hard white chalk between the marls near Hitchin, and C of the similar white chalk near Royston:—

	A.	B.	C.
Loss on ignition (organic matter) ...	2·14	·60	1·30
Calcium carbonate...	71·86	90·90	89·38
„ phosphate...	·82	·31	·31
„ sulphate	1·30	·10	·20
Magnesium carbonate	2·68	1·53	1·28
Lime	2·41	2·22	2·31
Oxide of iron and alumina	1·45	·47	·59
Oxide of manganese	2·07	·53	·20
Clay	6·00	·65	1·03
Quartz	3·49	·43	·96
Colloid silica	5·57	1·53	1·90
Alkalis and loss on analysis	·21	·73	·54
	100·00	100·00	100·00

It is noticeable that the lower marl is highly calcareous, containing no less than 74·54 per cent. of carbonates; while the white chalk is, as one would expect, a pure limestone, containing over 90 per cent. of carbonate, with very small amounts of clay and quartz.

CHAPTER XXV.

PHYSICAL AND GEOGRAPHICAL CONDITIONS IN THE TIME OF THE LOWER CHALK.

1. Evidence of Current Action at the Base of the Chalk.

The stratigraphical facts which have been recorded in connection with the basement beds of this stage at different localities prove that some considerable physical changes took place at the time when these basement beds were formed. It will be worth while recapitulating some of these facts in order that the evidence of increased current-action may come more clearly before the reader.

First, then, we saw that in Kent there was everywhere evidence of erosion at the top of the Gault; at Folkestone the sand of the *Stauronema* bed is piped into the underlying Gault; near Burham the top of the Gault is cut off abruptly and overlain by a layer of phosphatic nodules which have presumably been derived from it. At Eastbourne, in Sussex, there is an abrupt change like that at Folkestone, with a similar piping of Chloritic Marl into the underlying stratum. In the Isle of Wight there is a variable set of beds at the junction of the two formations, but most sections show an horizon where the material of one bed is piped into another; there are also layers of phosphatic nodules and lumps of partly phosphatised stone.

Throughout the greater part of Dorset the uppermost bed of the Greensand exhibits every sign of having been exposed to the action of a strong current for some length of time (see pp. 93 and 108). It is a hard calcareous rock, the surface of which is often phosphatised, and it forms a great contrast to the soft glauconitic chalk (with its basement layer of phosphatic nodules) which overlies it. In East Devon there are similar signs of erosion and evidence that currents were active throughout the whole epoch of the Lower Chalk, for at the most western localities the Chalk Marl is represented by a few feet of shelly and quartziferous limestone, above which is another plane of erosion, and a total absence of anything to correspond with the rest of the Lower Chalk.

In South Wiltshire and Hampshire there is generally more or less of a passage from one formation to the other, so that in this area a certain amount of deposition took place while erosion was in progress elsewhere. But in North Wiltshire, from near Calne to Swindon, there is an abrupt transition with distinct signs of erosion.

Northward, again, through Berkshire, Oxfordshire, Buckinghamshire, and into the western part of Bedfordshire there is always a passage from the Selbornian to the Chalk Marl, so that a large area here was out of the track of the strong eroding currents.

Beyond this, however, is another tract at least fifty miles in length, along which the Gault presents a surface of erosion and is overlain by the Cambridge Greensand or Nodule-bed (see p. 194). This eroded surface probably terminates somewhere below the Fens on the borders of Suffolk and Norfolk. North of it we have an area of slow deposition, with a complete and uneroded representative of the Gault overlain by a similarly condensed equivalent of the Chalk Marl. In Lincolnshire and Yorkshire also the deposition of calcareous sediment was continuous, so that there is no break, but a complete passage from "Red Chalk" to the Chalk proper.

From the above *résumé* it will be seen that the most marked signs of current action, with removal and sifting of material, occur (1) in Kent and Sussex, (2) in Dorset and Devon, (3) in North Wilts, (4) along the tract occupied by the Cambridge Greensand. It will be worth while seeing if the last can be traced to any distance beneath the chalk, and, if so, in what direction it runs.

A boring made at Culford in 1890* is important as showing that the eroded surface of the Gault does not extend far to the east of Cambridge and Soham, for in this boring the change from Chalk Marl to Upper Gault seems to have been like that near Stoke Ferry, in Norfolk.

The next nearest place where a boring has been made through the chalk is at Ware, about thirty miles S.S.E. of Cambridge, and twenty miles south-east of the termination of the outcrop of the Cambridge nodule bed in Bedfordshire. It is interesting to find that a sample, believed to have come from the base of the chalk below Ware, has all the characters of the nodule bed as formerly to be seen near Sharpenhoe in Bedfordshire. †

Nothing comparable to this nodule bed has been recorded from the boring at Cheshunt, but the samples preserved did not include one from the actual base of the chalk, so that one cannot positively state it to be absent there, more especially as it seems to be present under London. Describing the Chalk Marl in the boring at Meux's Brewery (Oxford Street), Mr. Whitaker observes ‡ "in a fine core from the base, at the office [of the Geological Survey], I saw a good specimen of the Cambridge phosphate bed (said to be six inches thick) with greensand and nodules passing up into regular Chalk Marl."

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* See Quart. Journ. Geol. Soc., Vol. l. p. 489.

† *Loc. cit.*, p. 504.

‡ Geology of London, Vol. ii. p. 167., Mem. Geol. Survey, 1889.

There is no note of its existence either at Richmond or at Streatham, and we know there is nothing like it along the outcrop in Surrey, but a similar bed appears at the outcrop in Kent, near Maidstone. At Chartham, near Canterbury, a boring proved only "eight inches of dark sand" at the base of the Chalk Marl* with Gault below. At Dover, again, in the shaft of the Dover Coal Exploration, there is but 3 feet of marly greensand with phosphate nodules resting directly on the Gault, as compared with 16 feet at Folkestone.

Thus, so far as the available evidence goes, it appears that the area of erosion occupied by the Cambridge Greensand can be traced southwards as far as London and probably thence into Kent. The facts suggest the existence of a strong current setting off the land east of Dover and flowing in a west-north-west direction to the latitude of London, where it was deflected northward in the direction of Ware, Hitchin, and Cambridge. It is, of course, just possible that the flow of the current was in a reverse direction, but the complete absence of any signs of current action at this particular epoch in Norfolk, Lincolnshire, or Yorkshire makes it very unlikely that such a current came from the north or north-east. It might possibly have set from the north-west through the Cheshire Straits across Stafford, Leicester, Northampton, and Huntingdon, but we have reason to believe † that the set of the current which brought the material of the Gault, was probably from the south-east, and it is most likely that the current which caused erosion of the Gault came from the same quarter. There is, moreover, another line of evidence which tells against the idea of a current from the north-west; this is as follows:—

The Cambridge Greensand has yielded many blocks and fragments of igneous and Palæozoic rocks, including pieces of granite, hyperite, basalt, felstone, gneiss, schist, conglomerate, red sandstone, slate, quartzite, and hornstone, with a few pieces of dark grey limestone. Some of them certainly resemble Scotch and Norwegian rocks, but the whole assemblage could not be matched in the north of England or in Scotland, nor, so far as is known, in Norway. Mr. Whitaker, however, has suggested that they may have come from the buried land which lay to the east of England.

It is true one cannot be quite sure that the rock fragments were brought by the current which eroded the Gault and formed the Cambridge nodule bed, for the stones may have been derived from the Gault as well as the phosphate nodules. Stones have actually been found in the Gault both at Cambridge and Folkestone, but those we have seen were of small size and always waterworn, whereas the erratics of the Cambridge Greensand are large angular and subangular blocks, some of them more than a foot in length and equal in mass to a cubic foot of rock. Some large blocks, however, have been found by Mr. H. Woods in the coprolite bed at the base of the Upper Gault at Stanbridge, near Leighton Buzzard (see p. 196). Similar large blocks have been found in the Chalk Marl of Burwell, in Cambridgeshire, and at Gayton, in Norfolk.* While, therefore, some of the rock-fragments in the Cambridge Greensand may have been derived from the Gault, it seems probable that most of them were dropped on the sea floor during the formation of that deposit.

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* See account given by Mr. Whitaker, Quart. Journ. Geol. Soc., Vol. xlii, p. 35.

† See Cretaceous Rocks of Britain, Vol. i. p. 412.

When they were first described † it was suggested that ice was the means of transport and it is certainly difficult to understand by what other means the larger blocks could have been carried, though those of smaller size might well have been transported by the agency of trees swept down by rivers in times of flood.

It is, of course, possible that there was a cold current from the north or north-east which met a warm current from the south-east, much as the Labrador current meets the Gulf Stream current at the present time, and that the stones were dropped by the melting of ice floes. It is also possible that these floes came from the coast of a vanished land which then united Scotland with Norway, and this would account for the likeness many of the fragments bear to Scotch and Norwegian rocks. If they had been brought by a current from the north-west we should expect that many of them would be traceable to existing north-western sources, which is not the case.

There remains Mr. Whitaker's suggestion that the transported fragments came from the eastern land, but until we know more of the rocks which formed this land it must remain only a suggestion. If such were their source we cannot call in the agency of icebergs, but river-ice such as is formed in the St. Lawrence at the present time and occasionally even in the Thames would be capable of transporting the blocks above mentioned. Even this, however, would indicate a colder climate than we generally associate with the Cretaceous period, but in this connection it is noticeable that coniferous wood is common in the Gault and Upper Greensand.

As mentioned on p. 344, there are proofs that another strong current flowed across Devon and Dorset, and there is good evidence of its having been strongest in the far western localities, its velocity diminishing in an easterly direction, though its influence is still visible in the Isle of Wight. Even at Cap la Hève, in Normandy, proofs of current action are very apparent in the bed which we regard as the equivalent of our Chloritic Marl.

So powerful was the action of these currents that for a time it was only in a comparatively small area that sediment was permitted to accumulate. The earliest Cenomanian sediments in Britain were the beds composing the sub-zones of *Catopygus columbarius* and *Stauronema Carteri*, and so far as at present known these do not extend westward into Dorset nor farther north than Berkshire, but spread eastward through Hants and Sussex to Folkestone and southward to the mouth of the Seine, and probably beneath the Paris basin, though that has not yet been proved.

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* See Quart. Journ. Geol. Soc., Vol. xliii. p. 554, and Mem. Geol. Survey Expl. of Sh. 65, p. 35.

† Quart. Journ. Geol. Soc., Vol. xxix. p. 11.

The surfaces of erosion which have been indicated above are not proofs of emergence above the sea-level of the period as many French geologists have imagined, but are only signs of some geographical change which for a certain time greatly increased the strength of the marine currents and prevented the deposition of much sediment, even where it did not cause actual erosion of the deposits already accumulated. That this change was due to a partial or general subsidence may be regarded as fairly certain, because the succeeding deposit is known to have extended beyond the limits of the underlying greensands and because this deposit is a chalky one containing much less terrigenous material than those of Selbornian age.

Limits of the Lower Chalk Sea.

So far as we can judge from the evidence at present available, it would appear that this subsidence was one affecting the whole area of deposition, so that the shore lines were everywhere carried back both on the eastern and on the western side of the Anglo-Gallic sea. On the western side shallow-water deposits of this age are preserved in France, Devonshire, the North of Ireland, and the West of Scotland. An outlier in the Cotentin, where five feet of Cenomanian sand rest directly on Palæozoic rocks, shows that they overlapped the beds which correspond to our Upper Greensand. In Ireland, also, the Glauconitic Sands which appear to represent the highest part of the Selbornian stage are very thin, and there seems reason to believe that they are overlapped by the "Yellow Sandstones" which apparently correspond to the Lower Chalk of England.*

Evidence of similar overlap is found again in the north-east of France, where the beds described by Professor Barrois extend north-eastward beyond the Gaize, and are themselves overlapped by the zone of *Actinocamax plenus* (see ante, p. 244).

Not only was the sea widened and deepened, but all the inlets of the western land must have been enlarged and lengthened, and it is probable that portions of this land were isolated from the rest. Thus the central part of France seems to have become an island in consequence of the Cenomanian sea passing between it and Brittany.† How far the inlet between Dartmoor and Wales was carried westward we have no means of knowing, nor can we say what has happened to the west of Wales, for there are no traces of Cretaceous deposits on the borders of St. George's Channel, and the history of the Irish Sea has yet to be written. It is very probable, however, that in the Jurassic and Lower Cretaceous periods there were deep and broad valleys between Wales and Ireland, draining northwards into a northern gulf, and it is possible that during the subsidence of the Lower Chalk age a communication may have been established between the northern gulf and the inlet to the south of Wales, in which case Wales would have been converted into an island.

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* See "The Cretaceous Strata of County Antrim," by W. F. Hume, D.Sc., Quart. Journ. Geol. Soc., Vol. liii. p. 540. For my own view of the age of the beds mentioned, see Students' Handbook of Stratigraphical Geology, p. 447, 1902.

† See "Etude palæogéogr sur le Détroit de Poitiers," par A. de Grossouvre, Comptes Rend. de l'Assoc. Franc. pour Av. Sci. 1901, p. 401.

When discussing the probable geography of the Selbornian age in a previous volume we saw reason to think that the Selbornian deposits once extended over the Cheshire plains and across the basin of the Irish Sea to the north-eastern corner of Ireland. If such a gulf existed at that time it must have been enlarged and extended during the subsequent Cenomanian subsidence. The glauconitic sands, which occur at the base of the Cretaceous series in Mull and Morvern and have been described by Professor Judd,* seem to indicate that this gulf extended northward into that district, so that Scotland was at any rate partially divided from Ireland, though there may still have been a land connection to the west of it.

In the region of the Pennine promontory it is not likely that there was much geographical change, for we should not suppose that a subsidence of 200 or even 300 feet would have narrowed it to any great extent; nor that such a subsidence would have carried the sea of the Lower Chalk very far northward in Yorkshire, but the absence of any Cretaceous outlier on the Yorkshire Moors leaves us absolutely without any evidence in that direction.

Thus so far as we can form an opinion the geography of the sea in which the Lower Chalk was accumulated did not differ very greatly from that of the preceding Selbornian epoch, except in being wider and deeper. All the surrounding tracts of land were reduced both in size and in elevation, and as a consequence less terrigenous material was carried into the adjoining seas.

Sedimentation.

Let us now consider the disposition of the sediments which were deposited in this Cenomanian sea after the disturbing and erosive influences had ceased and only the finest kind of terrigenous sediment was carried by the currents to be mingled on the sea floor with the calcareous ooze which is derived from the decay and disintegration of calcareous shells.

The chalk of the Am. varians Zone.—If in the interim above mentioned any change took place in the direction of the marine currents, it would appear that they subsequently resumed their former courses, for it is interesting to find that the more argillaceous facies of the Lower Chalk coincides very nearly with the area over which the Selbornian is most argillaceous. In other words, the Chalk Marl is more marly and less chalky over the whole of the east of England as far north as Mildenhall, in Suffolk, and westward as far as Berkshire, Hampshire, and the Isle of Wight. Beyond this area both to the west and to the north argillaceous matter rapidly disappears, and the material, which is still often called Chalk Marl, becomes a chalk with only a few included bands of marl. The lateral change from chalk marl to chalk in Dorset has been described on p. 107, and the similar change in Norfolk is mentioned on p. 209. Hence it would appear that the muddy sediment came from the same source as the Gault clay—namely, from the south-east.

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* Quart. Journ. Geol. Soc., Vol. xxxiv. p. 729, 1878.

The conditions in the south-west of England are especially worthy of attention. In the first place, the purity of the chalk and the small thickness which can be regarded as representing the Chalk Marl (zone of *Am. varians*) in southern and western Dorset seem to indicate clearness of water and absence of terrigenous sediment; but it is curious to find that this clear water was tenanted by a small amount of life.

It is still more curious to find that this area of pure chalk extending into Devon as far as Membury, while less than five miles further west the Chalk Marl is represented by a calcareous sandstone consisting mainly of large quartz grains. It is stated on p. 126 that this sandy zone of *Ammonites Mantelli* probably represents that part of the Chalk Marl which is absent in West Dorset; but if this is so, and if the Membury and Chard chalk is wholly or largely of later date than the zone of *Ammonites Mantelli* at Wilmington and Beer Head, how did it come to pass that the sandy beds are absent below the chalk, and that the chalk is absent above the sands.

The only explanation of these facts which has suggested itself to me is that the sands of the *Ammonites Mantelli* zone were originally deposited over a much wider area than that to which they are now restricted, that they extended far both to the northward and to the eastward, not only over the Mem aburynd Chard district, but far into the centre of Dorset. The very coarseness of the sands indicates the existence of a strong current, and we have only to suppose that this current became still stronger till it removed a large portion of the sand which had been accumulated; then it gradually slackened as further subsidence took place and the nodule bed which lies at the base of the chalk in West Dorset and Somerset was formed on the current-swept surface.

Those portions of the zone of *Ammonites Mantelli* which are preserved testify to accumulation under the influence of changing currents by the rapid variation in the thickness of the component beds within short distances (see Fig.31, p. 131), and by the surfaces of erosion which often occur between them. Their preservation may be attributed to one or other of two causes or to both combined; either they had become more consolidated than the portions which were destroyed or they lay out of the track of the strongest part of the current. The latter supposition will also serve to explain the non-deposition of any chalky Cenomanian sediments above the sandstones in the coastal region of Devon, for a subsequent subsidence would be very likely to change the course of the currents, and the central track of the strong current which had swept over Somerset and Dorset might very well have been diverted into a more southerly course, while its velocity would doubtless be at the same time diminished. It might still, however, be strong enough to prevent deposition of any kind over the area between Sidmouth and Lyme until the very close of the Cenomanian age. It is probable also that the establishment of such conditions was assisted by the slope of the sea floor, this being doubtless toward the north and east, so that the water was deeper in those directions.*

Passing over the wide area of Midland and eastern England, in which the zone of *Ammonites varians* is more or less argillaceous, we come to the northern region of purer sediment, which extends from Stoke Ferry in Norfolk across the Wash and through Lincolnshire into South Yorkshire. In this region there are no coarse sandy deposits, and there is consequently less difficulty in imagining the conditions under which the beds were formed.

The reduction of thickness and the more calcareous nature of the chalk shows that this portion of the sea floor was quite out of the range of the currents which carried muddy sediment. At Speeton, however, we evidently reach the border of a tract which was invaded by such a mud-bearing current, and the resulting deposit was a true chalk-marl. Having regard to the great distance between Stoke Ferry and Speeton, about 112 miles, it does not seem likely that the current carrying mud to the latter was a branch of that which carried mud to the former; it is more likely to have been a distinct current flowing from the north or the north-east.

It should be mentioned, however, that the comparatively coarse and shelly character of the Inoceramus-Beds near the base of the Chalk in this part of England testifies to the existence of a current strong enough to carry away the finer particles of chalky sediment that would otherwise have accumulated, leaving only the larger shell-fragments and the mineral grains. It is clear, however, that this was a ground-current sweeping the floor of the sea, while the mud-bearing currents may have been surface-currents. Consequently the current which is indicated by the Inoceramus-Bed may have come from quite a different direction, and possibly from the south-west, though there is really no evidence to decide from which direction it came.

The Totternhoe Stone is a repetition of the conditions indicated by the Inoceramus-Bed, only they extended over a larger area of the sea-floor. Mr. Hill considers that the structure of the Totternhoe Stone may be attributed to the action of a gentle but steady current in bearing away the fine material which forms so large a part of the beds above and below it (see p. 326). Current action is indicated also by the extremely even size of the constituent fragments, and by the layer of nodules which is so generally found at its base; these nodules being indurated and partially phosphatised pellets or pebbles of Chalk Marl.

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* Subsequent consideration of this problem has led me to think that there must have been some unequal crust-movements in Cenomanian time.

Now the current which carried away the finer material can hardly have been the same current which brought the argillaceous material of the marly chalk below. Moreover, the fact that in some places, as at Arlesey and at Tring, there are two beds of shelly stone divided by a band of marly chalk, is strongly suggestive of two currents, the prevalence of the one causing the formation of quite a different kind of deposit from that formed under the influence of the other. We need not imagine, however, that these currents were in actual conflict, because the one may have been a surface current, and that which controlled the formation of the Totternhoe Stone was certainly a bottom-current. It was probably only a temporary cessation or diversion of the ground-current which allowed of the deposition of the intercalated bands of chalk marl.

In the case of the Totternhoe Stone it is noticeable that it attains its maximum thickness in the counties of Cambridge, Hertford, and Bedford, and that it has not been traced to the south of Chilton, in Berkshire, although there are beds which resemble it in North Wilts and North Hants. On the other hand, it extends as a thin, but continuous bed through Norfolk, Lincolnshire, and Yorkshire, where the underlying beds are not marly. These facts seem to prove that the current which controlled its formation was quite unconnected with the mud-bearing current, and that it did not come from the south nor from the north, where the bed is thinner and less sandy than in Cambridgeshire. On the whole, it seems most probable that the ground current set from some westerly direction, either from the south-west or possibly from the inlet opening to the north-west; and that in either case it swept eastward and north-eastward outside the Pennine promontory.

The layer of phosphatic nodules which so often occurs at the base of the Totternhoe Stone, and the frequency of such nodules and of phosphatic fragments in the stone itself, are also evidences of current action. In this connection also may be mentioned the occasional occurrence of phosphatic nodules about the same horizon elsewhere, as at Punfield Cove, on the Dorset coast, and at Compton Bay, in the Isle of Wight.

These phosphatic nodules appear to be similar to those which frequently occur in modern sediments of all kinds within a certain distance of Continental coast-lines. It has been pointed out by Walther* that such phosphatic concretions are most frequent off those coasts where, owing to the meeting of warm and cold currents, the water is subject to marked and rapid changes of temperature, as off the Cape of Good Hope and on the east coast of North America, He thinks it probable that large numbers of marine organisms are killed by the changes of temperature at such places, and that an extensive deposit of decomposing organic matter is thus formed. In this way alternations of beds with and without phosphatic concretions may be produced. He is also of opinion that the concretions are formed in the deposit as it accumulates, the phosphatic material being separated out of solution and deposited round various kinds of foreign bodies present in the sediment.

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* Einleitung in die Geologie als historische Wissenschaft, p. 699, Jena, 1894.

Walther, however, does not explain very clearly how the solution of phosphate of lime may be formed, and on this point my colleague, Mr. J. J. H. Teall, sends me the following note:—"Decomposing organic matter gives rise to carbonic acid and ammonia. These will readily dissolve the bones of fish, and thus bring phosphate of ammonia and carbonate of lime into solution. If, then, this solution comes into contact with another containing an excess of carbonate of lime, precipitation of phosphate of lime will occur."

Chalk above the Totternhoe Stone.—In the higher part of the Lower Chalk there is clear evidence of the declining power of both the currents which seem to have played a part in the formation of the lower beds. The chalk above the Totternhoe Stone becomes gradually less grey and less shelly, till it merges into a nearly white chalk, and it was pointed out long ago by Mr. Hill* that this was due to the increasing preponderance of fine chalky matter and of calcareous spheres. The deposit finally assumes the character of an oceanic ooze, without any glauconite, and with no quartz grains which could not have been carried by the wind.

In the "rag-bed" of the country between Risborough and Dunstable we have evidence of a local and temporary recurrence to the conditions of the Totternhoe Stone, but in the whiter and upper part of the Lower Chalk there is no trace of current action and every indication that the deposit was formed in the open sea at some distance from land. In other words we may reasonably conclude that the Cenomanian sea had become both larger and deeper in consequence of a continued subsidence of the whole region, so the currents which set off the shore could not carry any terrestrial detritus into the more central parts of the sea.

Belemnite Marls.—Under these conditions some thickness of chalky ooze was slowly accumulated, but instead of a passage into the equally calcareous material of the Melbourn Rock, as we might have expected, we find nearly everywhere an interposition of argillaceous marl either in one or in two beds. It would seem, indeed, as if for a brief time there was a recurrence to the conditions of the Chalk Marl, mud-bearing currents being re-established over nearly the whole of the area of deposition.

There are, however, a few districts where there is either a complete or nearly complete absence of marl, and just such a passage from the Lower to the Middle Chalk as we should have expected to be the more general type of sequence. Thus in the north-west of Norfolk, where all marly beds are so conspicuously absent, there is no representative of the Belemnite marls. In South Wilts and

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* See Quart. Journ. Geol. Soc. Vol. xlii., p. 228 (1880).

North Dorset there is often only a single thin layer of marl, and in one locality at least the Melbourn Rock actually passes down into a marly chalk of ordinary type (see p. 108). In West Dorset, again, the marl bed is often either thin or absent, though in other places it is well developed.

On the other hand, there are places, as in East Dorset and in Sussex, where the marl swells out to a thickness of 12 or 14 feet. Another peculiarity of the horizon is that over a large area, from Berkshire to the border of Suffolk, its usual aspect is that of two thin layers of laminated marl with a bed of compact pure white chalk between them.

It is not very easy to understand what could cause such a sudden change in the conditions of deposition over such a large area, but it is clear that some special occurrence took place or some geographical change of more than local importance in consequence of which currents of considerable power were set in action, but it is evident also that these conditions did not last long, that they were of the nature of an interruption and could not be connected with the progress of a gradual and continued subsidence.

Current action is plainly indicated by the laminated character of the marls, by the occasional occurrence of brecciated beds, and by the actual erosion of underlying chalk which seems to have occurred in some places (see p. 179). The Midland facies, moreover, shows two distinct episodes of current action with an intervening period of quiet deposition. Lastly, we have a suggestive fact in the occasional occurrence of small pebbles of quartz and quartzite, two of which have been found in Cambridgeshire and one in Lincolnshire.

The most simple explanation of the facts which occurs to me is the supposition that there were two occasions or seasons of unusually heavy rainfall, causing great floods in the valleys of the larger rivers which discharged themselves into the Cenomanian sea; the volume and velocity of these rivers being thereby so greatly increased that their currents carried muddy sediment far out to sea, just as the Amazon and other large rivers do at the present time; only that what is usual and continuous in the case of the Amazon was an unusual and exceptional occurrence in the case of the rivers which opened into the Cenomanian sea.

The above hypothesis has the merit of invoking a natural cause, without the necessity of supposing any interruption to or reversal of the general movement of subsidence which is indicated by the nature of the preceding and the succeeding deposits. It will account for the sudden transition from nearly pure chalk to argillaceous marl, for the small thickness of the marly layers and for their episodal mode of occurrence; it will account for the local variations in the development of the marly beds and at the same time for the wide distribution of the argillaceous material. It will also explain the presence of the pebbles which are so likely to have been transported in the roots of trees and plants, many of which must have been carried out to sea under the circumstances above suggested.

Depth of Water.

Coming now to the difficult problem of endeavouring to gauge the depth of water beneath which the Lower Chalk was accumulated, we may first indicate some general considerations, and then discuss such actual evidence as is available.

First, then, the mere change from Gault mud or from malmstone to glauconitic sand and marly chalk does not necessarily mean an increase of depth, but only a change in the direction of mud-bearing currents. Opposite the mouths of great rivers terrigenous mud may be deposited at depths of over 1,000 fathoms, as, for instance, in the Arabian Sea and in the Bay of Bengal, where, but for the Indus and the Ganges, Globigerina ooze would doubtless be forming.

It is true that in the case of the Lower Chalk there is every reason to suppose that the change was brought about by continued subsidence, which widened the area of the sea at the expense of the surrounding land, lessened the volume of the rivers, and eventually opened up passages into other seas, by means of which the direction of the currents was greatly altered. Still, the actual amount of vertical subsidence which brought about the final change need not have been great; 200 feet is only a little over 33 fathoms, and 200 feet might well have been sufficient to submerge much land and to breach important isthmuses. Yet, if the depth of the water during the formation of the highest part of the Folkestone Gault was 300 fathoms, we should not regard an increase of 33 fathoms as a great accession of depth.

The size of the grains of mineral detritus in a deposit is rather an indication of distance from land than of the depth of water, except so far as the one depends on the other. At the base of the Chalk Marl large grains of quartz often occur from 2 to 3 mm. in diameter, and these are not likely to occur so frequently at a distance of more than 100 miles from land or at depths of more than 500 fathoms. They indicate the action of strong currents, but it is noticeable that in the south-east of England the mineral grains rapidly decrease in size upward; that those found in the grey marls seldom exceed ·5 mm.; while in the higher beds they seldom exceed ·05—a size which might occur in almost any depth.

We may next consider whether any of the fossil remains will afford us more definite evidence. The more highly organised creatures, such as Fish and Cephalopods, are of little value in this inquiry, because of their capacity to move about freely, and the same may be said of the Crustacea, for such recent Brachyuran forms as have kindred genera in the Lower Chalk range down to 500 or 600 fathoms, while the Macruran genera range to over 1,000 fathoms, and Cirripedes to much greater depths.

Gasteropoda.—More assistance might be expected from Gasteropods, most of which spend their adult lives on the sea floor, but many genera are now known to have such a great range in depth that they are of little use as bathymeters. Thus, for instance, the following genera, occurring in the Lower Chalk and now existent, all range from shallow water to depths of over 1,000 fathoms: *Aporrhais, Cerithiopsis, Dentalium, Emarginula, Fusus, Natica, Scalaria, Solarium, Trochus,* and *Voluta.* Taking those species of these genera which are found between 100 and 1,000 fathoms, I have calculated the average depth at which they occur on each side of the Atlantic on the authority of W. H. Dall* for the American side, and of Locard† for the European side. On the American side the average depth comes out at about 300 fathoms, and on the European side at 263 fathoms. But this result is of little value, because there is such great variation in the range of the species belonging to these genera, some of them only occurring in small depths, and others occurring at or ranging to the greater depths.

The only way to obtain a more useful result would be to compare the Cretaceous and recent forms species by species, to select those of the latter which most nearly resemble the former, and then to set down the average depth at which these representative species are found in modern seas. Such a comparison would require a much more special and detailed study of the fossil and recent shells than I have time or opportunity for.

Lamellibranchiata.—The remark just made with regard to the Gasteropods holds good also concerning the Lamellibranchs. Most of the genera which are found in the Chalk Marl (zone of *Ammonites varians*) occur also in the Upper Gault, and even some of the species are the same, or represented by slightly different varieties, such are *Arca carinata, Nucula pectinata, Cardita tenuicosta, Lima globosa, Pecten orbicularis, Neithea quinquecostata,* and *Plicatula inflata.* I think it may be said that there are no species in the Chalk Marl which could be regarded as indicating a greater depth of water than any in the Upper Gault.

There are, moreover, some genera which do not at the present day extend to any great depth. Thus *Ostrea* does not now extend beyond 300 fathoms, *Pinna* does not range beyond 200, nor *Avicula* beyond 350, *Tellina* and *Cardita* do not range beyond 600, nor *Spondylus* beyond 640. This, however, is negative evidence, and there is no reason why Cretaceous species of *Ostrea* and *Pinna* should not have ranged into deeper water than 300 fathoms, for Mr. E. A. Smith cites many recent species which live both in shallow and deep water, remarking that, "so far as our observations have reached the shells appear to be very little affected by the difference of the depth or the nature of the bottom."‡

The above remarks refer exclusively to the zone of *Am. varians* in the east and south-central parts of England; the fauna of the arenaceous beds which appear to represent the Chalk Marl in Devonshire exhibit quite a different facies. These beds contain a number of genera which are absent from or are very rare in the former, such are *Astarte, Corbis, Cardium, Crassatella, Cyprina, Gastrochœna, Pectunculus, Trigonia,* and *Solen* (*? Solecurtus*): genera which all now live in shallow waters, and might well be found together in about 50 fathoms. There can be little doubt that the water was much shallower in Devon than it was in Kent.

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* Catalogue of Marine Mollusks of the South-East coast of the United States, 1889.

† Coquilles Marines au large des côtes de France, 1899.

‡ *Challenger* Reports (*Lamellibranchiata*), Vol. xiii., p. 5.

From the *Brachiopoda* there is little to be learned, except that the conditions of the Lower Chalk were much more favourable to them than those of the Gault. From the Lower Gault of Folkestone Mr. F. G. Price records only the doubtful occurrence of one species. In the Upper Gault there are two genera and two species; in the Chalk Marl he found four genera and nine species. But this increase is probably attributable to the fact that these genera disliked muddy water then, as they do now, though they can live on clean sand, for out of twenty species found in the Chalk Marl generally fourteen occur in the Warminster beds.

Of *Echinodermata* there is a similar increase in number both of species and of individuals in passing upward to the Chalk Marl in the south-east of England, as shown in the following table:—

	Genera.	Species.
In the Lower Gault - - - - - - -	3	4
In the Upper Gault - - - - -	5	8
In the Chalk Marl - - - - - -	11	26

This increase may be partly attributable to the same cause, but as only fourteen species range up from the Warminster beds into the Chalk Marl of Wiltshire and the Isle of Wight, some of those in the latter may have come in with deeper water.

Foraminifera.—These minute organisms probably furnish us with better bathymetric evidence than any other class, because so many of the Cretaceous species have survived without change to the present day, and because the range and distribution of the recent species is now fairly well known.

The Foraminifera found in a deep-water oceanic deposit differ from those found in the lesser depths nearer to land in the larger proportion of pelagic species and in the smaller number of species that live on the bottom. Shallow-water deposits on the other hand generally contain a number of arenaceous forms, whose tests are formed largely or entirely of minute grains of sand.

The abundance of such Arenaceous Foraminifera in the marly chalk of the *Am. varians* zone, their scarcity in the higher beds, and the significance of these facts was first pointed out by Dr. A. F. Hume*; the significance being that at the present day the coarser arenaceous Foraminifera are abundant down to the depth of 400 fathoms, but beyond that depth they rapidly become scarce, only a few of the more widely distributed species being found at greater depths. He also indicated the remarkable resemblance that exists between the foraminiferal fauna of the Chalk Marl and the assemblage found near Culebra Island, in the West Indies, at 390 fathoms; thus in the Chalk Marl there are three common species of *Textularia* (*T. turris, T. trochus,* and *T. agglutinans*), and the only locality where these three have been found existing together is Culebra. *T. turris,* indeed, has only been found at two other places—viz., in the Bahama Channel at 438 fathoms, and off Pernambuco at 350 fathoms. Other species common to the Chalk Marl and the Culebra station are *Gaudryina pupoides, Bulimina Presli, Haplophragmium latidorsatum,* and *Ammodiscus incertus.*

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* Chemical and Micro-Mineralogical Researches on the Upper Cretaceous Zones, p. 81, London, 1893. See also Natural Science. Vol. vii., p. 270 (1895).

Again, with reference to the Miliolines we find another significant coincidence, Dr. W. B. Carpenter having long ago pointed out that the Miliolines of the Chalk Marl are small and delicate, like those which now occur in depths between 300 and 500 fathoms.

The above mentioned considerations certainly make it probable that the Chalk Marl of the south-eastern and south-central counties was formed at a depth approaching but possibly rather less than 400 fathoms. This conclusion is greatly strengthened by the contrast exhibited in the foraminiferal fauna of the upper part of the Lower Chalk. On this point Dr. Hume makes the following remarks: "In the more central portions of the mass of the Lower Chalk it is of the greatest interest to note that all the Textularians disappear, except the deep-sea form (*T. agglutinans*), and a very minute species which only occurs in the higher beds and in the Middle Chalk. . . . The upper beds of the Lower Chalk, both in the Isle of Wight and near Lewes, are chiefly characterised by the presence of a particular Bulimine (*B. variabilis*), together with some of the above typical deep-sea forms."*

Finally, he comes to the conclusion that "a depth of over 400 fathoms was attained before the Lower Chalk period closed;" in other words, it would seem that in passing upward from the Chalk Marl to the beds of nearly white chalk which underlie the Belemnite marls, we are tracing the effects of a subsidence which carried the area through the bathymetrical limit of 400 fathoms, and that the zone of *Holaster subglobosus* was formed in water which finally approximated to a depth of 500 fathoms.

We think that many parts of the Lower Chalk must, when deposited, have been similar to the calcareous oozes which are now found off the coasts of Yucatan and Florida in depths of from 350 to 860 fathoms. These deposits contain from 68 to 83 per cent. of calcium carbonate, with from 15 to 7 per cent. of soluble siliceous organisms, and the mineral particles in them average about ·07 mm. in size, rarely exceeding ·1 mm.

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* The Genesis of the Chalk, Proc. Geol. Soc., Vol. xiii., p. 211.

CHAPTER XXVI.

GENERAL ACCOUNT OF THE MIDDLE CHALK OR TURONIAN STAGE.

DEFINITION AND LIMITATION OF THE STAGE.

There have been several attempts to establish a *Middle* or *Medial* division of the English Chalk as mentioned in a previous chapter (see p. 4); but the first endeavour to found such a division on a strictly palæontological basis was made by Caleb Evans in 1870.* His "Middle Chalk," however, consisted of but one zone, that which is now known as the zone of *Terebratulina gracilis,* and he did not attempt to trace it beyond the immediate neighbourhood of the line of section which he described.

It was reserved for Professor Barrois, in 1876, to show that we possessed in England a full and complete equivalent of the Turonian of the North of France; that its lowest zone with *Inoceramus mytiloides* could be traced without difficulty from Dorset to Norfolk, and at each extremity of the Wealden area; and that its upper limit was defined by the "Chalk Rock" of Mr. Whitaker.

The survey of the Cambridgeshire Chalk by Mr. Penning and myself convinced us that in this county the formation fell naturally into three great divisions, and the general results of our work were expressed in the following terms†:—

"(1) That the zones of life [in the Cambridgeshire Chalk] are similar to those established elsewhere, and have been actually traced over a considerable area.

"(2) That there are two breaks of more or less importance marked by the occurrence of the hard rocky beds which are termed the Melbourn Rock and the Chalk Rock.

"(3) That a middle division of the Chalk is thus marked off, and that its establishment is confirmed by the palæontological evidence."

The facts on which this "Middle Chalk" was founded were fully set forth in the Geological Survey Memoir on the Neighbourhood of Cambridge published in 1881. Since that time there has never been any doubt about the lower limit of the Middle Chalk, the Melbourn Rock being an horizon which is easily recognised and easily followed across the country, except in the western part of Dorset. Its upper limit, again, is conveniently marked by the Chalk Rock wherever that rock is developed as a single set of hard rocky beds, but where this is not the case upper limit of the Middle Chalk is less definite.

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* On some Sections of Chalk between Croydon and Oxsted, Geol. Assoc. Separate Paper, (1870).

† Geol. Mag., Dec. II., Vol. vii., p. 254 (1880).

In the publication above mentioned the Middle Chalk included three zones, the succession being as follows:—

Middle Chalk
3. Zone of Holaster planus, including the Chalk Rock.
2. Zone of Terebratulina gracilis.
1. Zone of Rhynchonella Cuvieri or Inoceramus mytiloides, with the *Melbourn Rock* at its base.

The question of what ought to be regarded as the zone of *Holaster planus,* and whether the Chalk Rock should be placed at the top of the Middle Chalk or the base of the Upper Chalk, are points upon which we have spent much time and consideration, for even where the Chalk Rock is well developed there is not always a clearly marked plane of division either at its base or at its top, such as there is generally between the Lower and the Middle Chalk.

The history of the zone of *Holaster planus,* so far as England is concerned, may be summarised as follows. Hébert, writing in 1874, indicated the zone as comprising the central part of the "nodular chalk" of Dover.* Professor Barrois in 1876† traced this zone through various parts of England, and regarded the Chalk Rock as its equivalent. The result of collecting in Cambridgeshire between 1876 and 1877 showed that *Hol. planus* was fairly common below the Chalk Rock, and in 1880 it was proposed to group 50 or 60 feet of this soft chalk with the Chalk Rock in a zone of *Holaster planus.*‡

The Dover section was again described in 1886,§ and as the *Holaster* was found to be commonest in the lower beds, while *Micraster,* especially the species *breviporus* (= *M. Leskei*), was commoner in the upper part, it was proposed to make two zones, one of *Holaster planus* and another of *Micraster breviporus.* This, however, has not proved satisfactory, the faunas are not sufficiently distinct, and the fauna of the Chalk Rock is found both in and above the zone of *M. breviporus.*

It is, no doubt, quite possible to indicate at Dover a set of beds characterised by a special fauna, of which *H. planus* might be taken as the index, but there is no well marked summit to such a zone, which graduates up into that usually known as the zone of *Micraster cortestudinarium.* Moreover, the zone so defined may be regarded as the expansion of the Chalk Rock, but for that very reason is not the equivalent of the zone of *Holaster planus* as defined in 1880 for Cambridgeshire and in 1889 for the counties of Oxford and Buckingham.‖

The fact is that *Holaster planus* ranges through a considerable thickness of chalk, commencing high up in the *Terebratulina* zone, and dying out in that of *Micraster cortestudinarium.* It is not, of course, necessary that the range of the species which is chosen as the index of a zone should be restricted to that zone, but only that it should be most common within such limits; thus we are not obliged to include the chalk below the Chalk Rock in this zone just because *Holaster planus* occurs in it.

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* Bull. Soc. Géol. de France, Ser. 3, Tom. II. p. 423.

† Recherches sur le Terr. Crét. Sup., passim.

‡ See Geol. Mag., Dec. II., Vol. vii. p. 248.

§ By William Hill. See Quart. Journ. Geol. Soc., Vol. xlii. p. 232.

‖ See Memoirs of the Geological Survey, Geology of the Neighbourhood of Cambridge (1881), and Geology of London (1889).

Mr. H. Woods has pointed out* that the Chalk Rock facies of this zone would be more conveniently indicated by the name of *Heteroceras reussianum,* a species which is widely distributed and has been chosen as the index for the zone in Germany. The only objection to this is the great rarity of the *Heteroceras* in France and the South of England.

But, having defined the zone of *Hol. planus* as that where this fossil is generally most abundant, and is associated with the fauna of the Chalk Rock, we are next faced by the question whether this zone should be included in the Middle Chalk or not. The first consideration should unquestionably be given to the fauna, and this has been carefully studied by Mr. H. Woods. Of the 56 species of Cephalopoda, Gasteropoda, and Lamellibranchiata examined by him, no fewer than twenty-five are at present only known in the Chalk Rock beds; of the remainder nine or ten have an exclusively downward range, and the only two which range up and not down are *Lima granosa* and *Lima Hoperi.* Of Brachiopods there are only two which are specially Senonian—viz., *Terebratula carnea* and *Rhynchonella octoplicata.* Of Echinoderms eight species are mentioned by Mr. Wood, and two others are now known to occur: of these four range both up and down, four are species which only range upwards (*Cardiaster ananchytis, Echinocorys vulgaris, Micraster præcursor* and *M. cortestudinarium*). The two other species mentioned by Mr. Woods, I regard as of doubtful occurrence in Chalk Rock; these are *Galerites albogalerus,* very rare and possibly a rather flattened specimen of *G. subrotundus,* and a doubtful specimen of *Cyphosoma spatuliferum.*

Mr. Woods remarks that "on the whole I am inclined to think that the affinities of the fauna are closer to the Turonian than to the Senonian." I am of the same opinion; moreover, E. Hébert, Professor Barrois, and other French geologists had previously come to the same conclusion, and of late years it has been usual in France to include the zone of *Holaster planus* in the Turonian.

Are we, then, to place the upper limit of our Middle Chalk at the top of this zone of *Hol. planus* or *Heteroceras reussianum?* Unfortunately the zone has no definite top which can be followed for any great distance, for beds having the lithological character of the Chalk Rock occur at various horizons above the lowest and most fossiliferous bed, while in some districts there are no such rock-beds at all. Neither is there at any horizon such a marked change of fauna as would enable us to be sure when we passed from one zone to another, except in those districts where typical Chalk Rock is well developed and fossiliferous.

There is, in fact, a very close relationship between the zones of *Holaster planus* and *Micraster cortestudinarium;* so close, indeed, that I am inclined to think the chief faunal difference between them is the absence in the latter of those species which have hitherto been only found in the Chalk Rock. Consequently, I am driven to the conclusion that if the zone of *Holaster planus* has to be included in the Middle Chalk, the zone of *M. cortestudinarium* must also be taken into the same stage. This is the conclusion to which Schlüter came when dealing with the Chalk of Westphalia,* and to which Professor Barrois also came with respect to the Chalk of France in 1878.†

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* Quart. Journ. Geol. Soc., Vol. lii., p. 70, (1896).

But if we adopted this arrangement we should be as far as ever from having a satisfactory base for our Upper Chalk, for though many species which are common in the zones of *Hol. planus* and *Micr. cortestudinarium* die out in the zone of *M. coranguinum* they seem to do so gradually, and we have not been able to discover any horizon which can be followed through the country as a line of division between the zones of *M. cortestudinarium* and *M. coranguinum*.

On the other hand, there are few places where there is much difficulty in drawing a line at the base of the Chalk Rock or of the beds which correspond with it; this line has indeed been actually drawn over a large part of England, it is engraved on many of the maps of the Geological Survey, and the chalk above it has generally been described in Survey publications as Upper Chalk. It has consequently been decided to continue this arrangement and nomenclature. In this memoir, therefore, the Middle Chalk will be regarded as consisting of two zones only, namely:

2. The zone of *Terebratulina.*
1. The zone of *Rhynchonella Cuvieri.*

It must be remembered, however, that the *Terebratulina* zone of this memoir will include all the chalk which lies below the Chalk Rock of Oxfordshire and Buckinghamshire, and consequently takes in that which was described as the zone of *Holaster planus* in the memoir on the Geology of London (1889); it also includes some beds in Dorset and in the Isle of Wight which have been regarded hitherto as Upper Chalk.

The Middle Chalk is thickest in the south-east of England, where it has a maximum of 240 feet, thence it diminishes westward till it is only about 130 feet in South Dorset and less than 100 feet in North Dorset, but increases again in Devon to 140 feet. In parts of Wiltshire it is only 80 or 90 feet thick, but thickens northward till it reaches a maximum of 230 feet in Cambridgeshire, but again thins to little over 100 in Norfolk.

ZONES OF THE MIDDLE CHALK.

Zone of Rhynchonella Cuvieri.—This zone was first established in France by Professor Hébert (1866) as the zone of

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* Verhandl. des naturh. vereins der Preuss. u. Westf. xxxiii., Jahrg. 4 folge iii. Band. p. 330.

† Terr. Crét. des Ardennes, Ann. Soc. Géol. Nord. Tom. v., p. 434.

Cidaris, hirudo, but Dr. Barrois* in 1873, preferred to call it by the name of *Inoceramus labiatus,* and it is so designated in his "Recherches sur le Terrain Crétacé Supérieur." (1876.) This species, however, is more correctly called *I. mytiloides* (see Fig. 57).

When describing the Chalk of Cambridgeshire in 1880 and 1881†, I proposed to take *Rhynchonella Cuvieri* (Fig. 62) for the index species, as the typical form of this shell was generally abundant in the zone. This has been accepted by subsequent writers, and it is now usually known in England by this name.

It coincides with the "chalk without flints, but with many thin beds of organic remains" (nodules) of W. Phillips' description of the Dover Chalk ‡; and with Beds viii. and ix. of Mr. Price's section in 1877. § It is also to be identified with the Upper Marden Park Beds of Mr. Caleb Evans in Surrey.||

From its more or less nodular character and its creamy white or yellowish tint, it forms a contrast to the grey Belemnite marl at the top of the Lower Chalk and to the compact white chalk which generally underlies that band. This nodular character is most marked at the base of the zone, and the lowest beds over the greater part of England form a band of hard nodular rock, to which the name of Melbourn Rock was given in 1880, from the village of Melbourn, near Royston, in Cambridgeshire.

The Melbourn Rock may be described as a hard nodular chalky limestone, forming three or four massive beds when quarried, but weathering into a series of nodular and less nodular layers. The rock consists of a compact matrix in which small lumps or nodules of hard white chalk are arranged in planes or layers. The thickness of such rocky chalk varies in different places, but in the southern and midland counties it is generally from 8 to 10 feet; it passes up, however, into the hard bedded shelly chalk of the overlying zone, the small nodules becoming fewer and fewer and the chalk more compact, but more rough and shelly. The lower part of the rock often has a greenish-white tint and a marbled appearance from the presence of a greenish-grey marl which is arranged in wavy layers round the nodules; this part generally forms one massive bed 3 or 4 feet thick, and the nodules are less regularly arranged than in the higher part, which generally splits into two or three beds and is of a yellowish-white colour.

Mr. Hill remarks,¶ "There seems to be every gradation in the definition of the individual nodule from a well-defined sharply-angular fragment to the nodule whose shadowy outline blends with and is scarcely traceable in the mass of the chalk. In size

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* Note sur le Terr. Crét. entre Saint Omer et Boulogne, Mem. Soc. des Sciences, Lille, Tom. xi.

† See Geol. Mag., Dec. 2, Vol. vii. p. 248, and the Geology of the Neighbourhood of Cambridge, Mem. Geol. Survey, 1881, p. 60.

‡ Trans. Geol. Soc., Ser. 1, Vol. v. p. 16.

§ Quart. Journ. Geol. Soc., Vol. xxxiii. p. 431.

|| On some sections of Chalk between Croydon and Oxted, Geol. Assoc., Separate Paper.

¶ In "Geology of London," Mem. Geol. Survey, 1889, Vol. i., p. 522.

they vary greatly, from a minute particle not larger than a pin's head . . . . . to the rounded lump to which young oysters may often be found adhering." He also points out that the shapes and outlines of the nodules can be seen very well if a hard specimen of the rock be ground down and smoothed to a level surface.

Fossils are seldom found in the lower part of the rock except the small attached valves of young oysters which occasionally occur on the nodules; but *Rhynchonella Cuvieri* and a few other species occur in the upper beds, ranging thence through the zone of *Rhynchonella Cuvieri*.

The hard and nodular character of the Melbourn Rock enables it to resist atmospheric disintegration better than the blocky and marly Lower Chalk, so that its outcrop generally makes a well defined feature. When the Middle Chalk is fairly thick and the dip is slight there is generally a double escarpment, the first slope being capped by the Melbourn Rock and the second slope by the Chalk Rock. The boundary line of the Melbourn Rock has been engraved on all the maps of Chalk areas published by the Geological Survey since 1880.

The Melbourn Rock is thickest in Kent and Sussex, and was described as the "Grit Bed" by Mr. Price. It is traceable westward into Dorset and northwards into Norfolk, but ceases to be distinguishable from the rest of the zone in the north-west of the latter county.

Upwards the Melbourn Rock passes into a rather hard and rough kind of chalk, somewhat yellowish, and lying in regular beds which are frequently divided by layers of loose marly chalk. Nodules like those in the Melbourn Rock are still abundant in the lower part of this chalk, but gradually disappear in the higher beds. The shells of *Inoceramus mytiloides* are abundant in these beds, and their broken fragments, large and small, make up a considerable proportion of its mass. Scattered nodules of flint sometimes occur in the higher beds, but they are never frequent.

Rhynchonella Cuvieri is common throughout these beds, and in many localities *Cardiaster pygmæus*, *Discoidea Dixoni*, and *Galerites subrotundus* may be found. Micrasters are rarely found in this zone, except in Devonshire, where *Micraster corbovis* and *M. Leskei* are not uncommon in association with large *Cardiaster pygmæus* quite at the base of the zone. The characteristic Ammonite of the zone is *Am.* [*Acanthoceras*] *nodosoides* (see Fig. 56), though it cannot be called common.

The thickness of this zone, including the Melbourn Rock, does not vary greatly in the southern and midland counties, where it is generally between 60 and 80 feet thick, the chalk rapidly losing its nodular and shelly character at this distance from the base. When traced northward, however, it diminishes in thickness, being only 15 feet thick in Lincolnshire and still less in Yorkshire. On the Devon coast also it is in some places only 14 feet in thickness.

The Terebratulina Zone.

This zone was established in France by Professor Barrois in 1873, and identified in England by the same author in 1876. Since that date it has been known as the zone of *Terebratulina gracilis* both in England and France, but I am informed by Dr. F. L. Kitchin that the true *Ter. gracilis,* so far as we know, is restricted to the higher part of the Upper Chalk, and that the form which is so abundant in the Middle Chalk is that named *Ter. gracilis,* var. *lata,* by Mr. Etheridge in 1881.* (See Fig. 59.)

Mr. E. T. Newton agrees with Dr. Kitchin in regarding this form as distinct, but they consider that until the nomenclature of the species belonging to this genus is definitely settled it is best to write this form as *Terebratulina gracilis* var. *lata,* Eth.

While therefore it is clear that we cannot continue to speak of the Middle Chalk zone as that of *Ter. gracilis,* it would be premature to call it the zone of *Ter. lata,* because this may not be the rightful name of the species or variety. Consequently in this volume we shall call it simply the *Terebratulina* zone, using the name *lata* only where the occurrence of that form is mentioned, but entering it in all fossil lists as *Terebratulina gracilis,* var. *lata.*

This zone is the "chalk with few flints" of W. Phillips's section at Dover (1834),† and corresponds with the Upper Marden Park Beds of Caleb Evans in Surrey (1870). It exhibits very uniform characters throughout the southern counties and as far north as the borders of Suffolk and Norfolk. The lower part consists of rather soft dull white chalk, with occasional thin seams or layers of soft grey marl, which is more or less argillaceous. The bedding of the chalk between the layers of the marl is generally obscure, so that it comes away in large massive blocks. The chalk which succeeds is similar, but contains layers of flint nodules as well as seams of marl. In the South of England the flint-beds are few and far between except in Devonshire, where they are very numerous and caused this zone to be mistaken for Upper Chalk. In the counties of Cambridge, Suffolk, and Norfolk also they are more numerous than in the south, and are often elongate or finger-shaped, and curved or horn-shaped. In Lincolnshire and Yorkshire layers of flints are very frequent.

The limits of the zone have already been discussed (p. 360), and we need only repeat that in this memoir it is considered to extend up to the base of the Chalk Rock wherever that is present. It is thus strictly equivalent to the *Ter. gracilis* zone of Professor Barrois, and to that so called in the Survey Memoir on the Neighbourhood of Cambridge (1881).

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* Geology of the Neighbourhood of Cambridge, Mem. Geol. Survey, p. 147, Pl. 3, Fig. 14.

† Trans. Geol. Soc., Vol. v. p. 16.

After *Terebratulina,* the commonest and most characteristic fossil of this zone is *Galerites subrotundus.* *Inoceramus mytiloides* ranges up into it, and a larger species, the *Inoc. Cuvieri* of Sowerby, is also common. *Spondylus spinosus* is another fossil of frequent occurrence. *Holaster planus* makes its appearance in the higher beds, and is associated with *Micraster corbovis* and *M. Leskei.* The Ammonites which occur in this zone are *Am.* [*Prionotropis*] *Woolgari, Am.* [*Pachydiscus*] *peramplus,* and a form which is generally known as *Am.* [*Haploceras*] *lewesiensis,* but may be a different species from that occurring in the Lower Chalk; none of them are of common occurrence. Fish remains are common in some places, and *Ventriculites* are of frequent occurrence in the higher beds.

In the south-eastern and midland counties the thickness of the *Terebratulina* zone is from 130 to 160 feet, but westward it thins greatly till in some parts of Dorset it is not more than 50 feet thick. Northward also from Cambridgeshire it becomes rapidly thinner, and in Norfolk it is apparently only about 60 feet thick; in Lincolnshire, however, it is thicker again, and is well developed in Yorkshire, exhibiting a great thickness of flint-bearing chalk in the cliffs near Speeton.

Comparative tables showing the development of the Middle Chalk in various parts of England will be found on pp. 409 and 558.

Fossils of the Middle Chalk.

The fauna of the Middle Chalk differs very considerably from that of the Lower Chalk. Very few species range up from the Lower Chalk into the zone of *Rhynchonella Cuvieri,* and though some do reappear in the Chalk Rock (zone of *Holaster planus*), the statement made in 1880* still remains true—namely, "that a distinct palæontological break occurs at the horizon above mentioned, and that a large number of species became extinct or migrated to other areas." Perhaps the most noticable feature of the Middle Chalk fauna is the incoming of the genus *Micraster;* in Devonshire two species of this genus are not uncommon in the lower part of the zone of *Rhynchonella Curieri,* and *Micraster corbovis* is not uncommon in the higher part of the *Terebratulina* zone in Kent, Sussex, Cambridgeshire, and Suffolk. These and the other English species of *Micraster* have been recently carefully distinguished and described by Dr. A. W. Rowe.†

On the whole the Middle Chalk is not rich in fossils, though individual species like *Rhynchonella Cuvieri, Terebratulina lata,* and certain species of *Inoceramus* are often abundant.

Reptilia.—So far as we are aware few Reptilian remains have been recorded as coming with certainty from the Middle Chalk, but there is no reason to doubt that such remains occur in this part of the Chalk. *Cimoliosaurus Bernardi,* for instance, is recorded by

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* Geol. Mag., Dec. 2, Vol. vii., p. 255.

† See Quart. Journ. Geol. Soc., Vol. lv., p. 494. (1899.)

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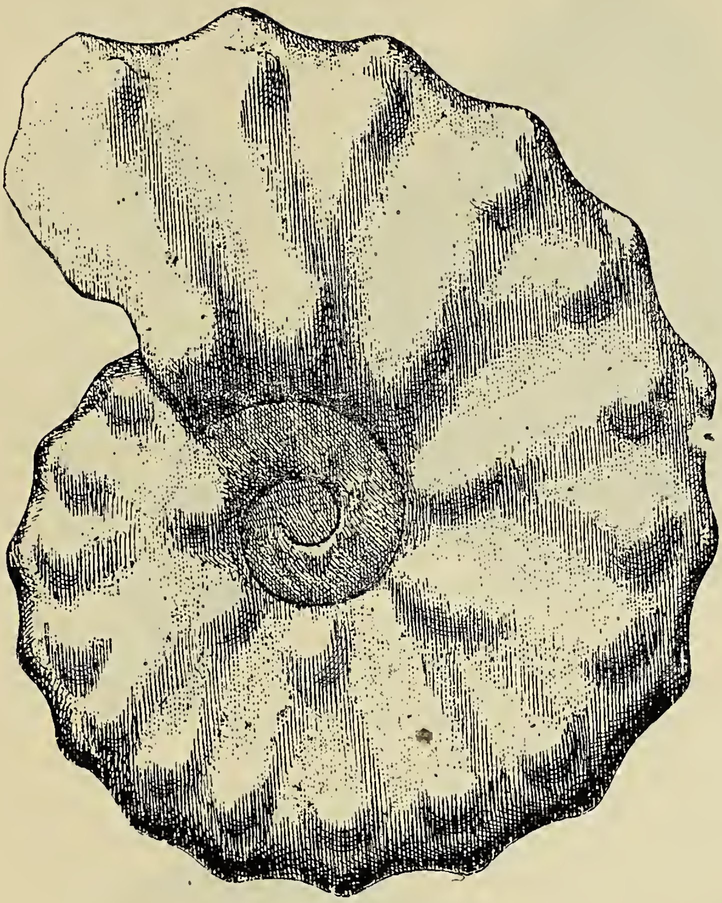

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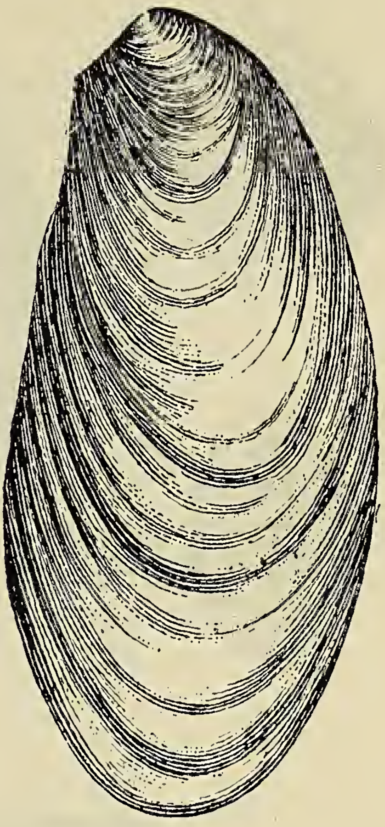

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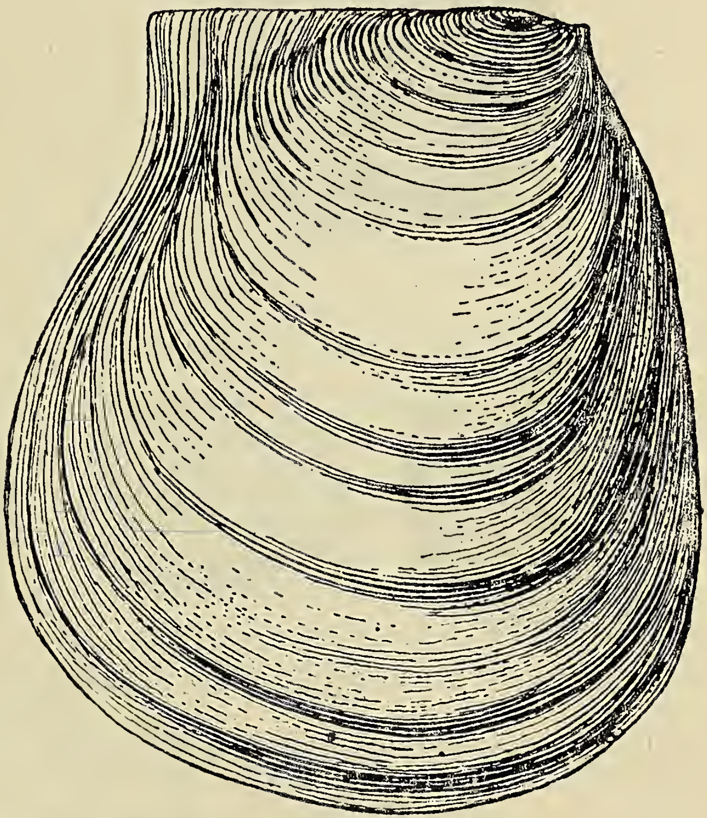

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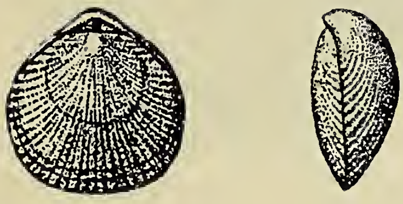

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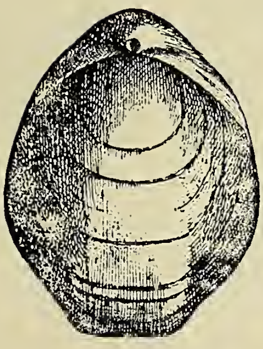
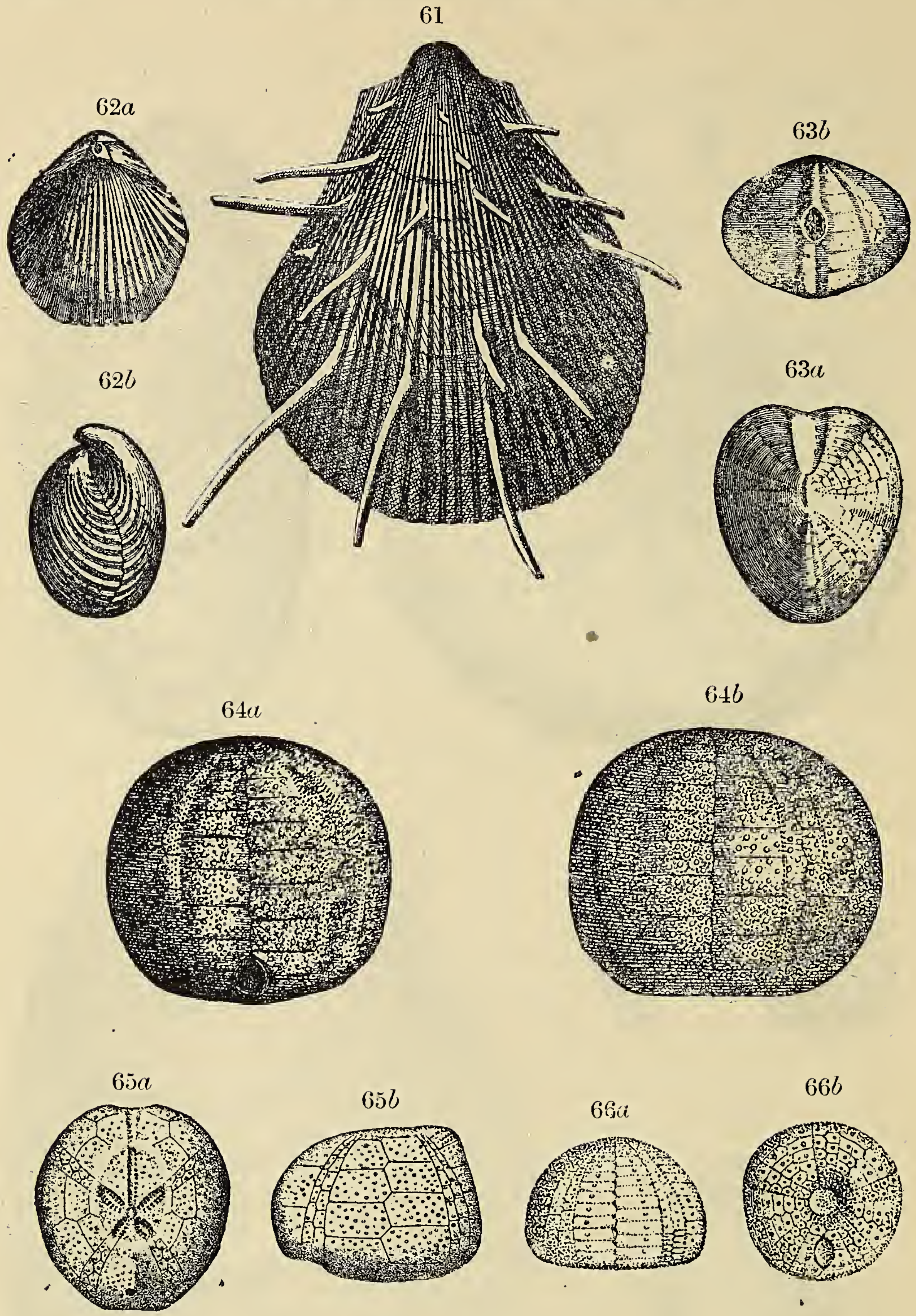


Fossils of the Middle Chalk.

Fig. 56.—Ammonites [Acanthoceras] nodosoides, *Schloth.* $\frac{3}{4}$ nat. size.
Fig. 57.—Inoceramus mytiloides, *Sow.* Nat. size.
Fig. 58.—Inoceramus Cuvieri, *Mant.* Small specimen, nat. size.
Fig. 59.—Terebratulina gracilis, var. lata, *Eth.* Three times nat. size.
Fig. 60.—Terebratula semiglobosa, *Sow.* Nat. size.



Fossils of the Middle Chalk.

Fig. 61.—Spondylus spinosus, *Sow.* (Nat. size.)
Fig. 62.—Rhynchonella Cuvieri, *d'Orb.* *a*, front view; *b*, side view. Enlarged.
Fig. 63.—Cardiaster pygmæus, *Forbes.* *a*, apical view; *b*, posterior view. Enlarged.
Fig. 64.—Galerites subrotundus, *Mant.* *a*, front view; *b*, side view. Nat. size.
Fig. 65.—Hemiaster minimus, *Ag.* *a*, side view; *b*, apical view. Enlarged by ½.
Fig. 66.—Discoidea Dixoni, *Forbes.* *a*, side view; *b*, basal view. Twice nat. size.

Owen as obtained from the chalk-pit at Houghton, near Arundel, and the larger pits there are in Middle Chalk.

Mr. Hill found a tooth of *Polyptychodon* in the zone of *Holaster planus* at Dover.

Pisces.—Remains of Fish are abundant in some localities, especially in the counties of Kent and Sussex. Many of the species are the same as those occurring in the Lower Chalk, such as *Ptychodus decurrens, Pt. mammillaris, Macropoma Mantelli* and *Beryx* (*Ctenothrissa*) *radians.* There are also a few such as *Oxyrhina crassidens* and *Ptychodus Oweni,* which have as yet only been recorded from Middle and Upper Chalk.

Cephalopoda.—Remains of large Ammonites occur occasionally in the lower part of the Middle Chalk, and the small species *Am.* [*Prionocyclus*] *Neptuni* has been found by myself in Devon and identified by Mr. H. Woods. The following is a complete list of the species which have been recognised in this stage:—

Ammonites [Haploceras] catinus, *Mant.*
„ [Acanthoceras] Cunningtoni, *Sharpe*
„ [Haploceras] lewesiensis ? *Mant.*
„ [Prionocyclus] Neptuni, *Geinitz*
„ [Acanthoceras] nodosoides, *Schlüter.* (Fig. 56.)
„ [Pachydiscus] peramplus, *Mant.*
„ [Acanthoceras] rusticus, *Sow.*
„ [Prionotropis] Woolgari, *Mant.*

Gasteropoda.—Fossils of this class are very rare in the Middle Chalk, except for occasional specimens of *Pleurotomaria perspectiva*, but *Aporrhais Mantelli,* and *Solariella gemmata* (=*Turbo gemmatus*) have also been found.

Lamellibranchiata.—The commonest bivalves in the Middle Chalk are species of *Inoceramus* (Figs. 57 and 58); the lower beds are the home of *Inoc. mytiloides* (the *I. labiatus* of French geologists), and the higher beds contain *Inoc. Cuvieri* with other species not yet clearly defined. *Spondylus spinosus* (Fig. 61) first occurs in the *Terebratulina* zone, and thence ranges upwards into Upper Chalk. A few others, such as *Pecten Beaveri, Ostrea vesicularis,* and *Spondylus latus,* range up from the Lower Chalk.

Brachiopoda.—In the Middle Chalk Brachiopods are often very numerous individually, but do not belong to many different species, and the following are those usually found, all except *Terebratulina lata*, ranging up from below.:—

Rhynchonella Cuvieri, *d'Orb.* (Fig. 62.)
Terebratula semiglobosa, *Sow.* (Fig. 60.)
Terebratulina gracilis, *Schloth*, var. lata. *Eth.* (Fig. 59)
„ striata, Wahl.

Echinodermata.—Members of this class are fairly abundant throughout the Middle Chalk, but more especially in the lower portion, and, so far as I know, only three species range up from the Lower Chalk; these are *Galerites castanea, Hemiaster minimus* and *Glyphocyphus radiatus.* The following are the most characteristic species:—

Cardiaster pygmæus, *Forbes* (Fig 63).
Cidaris hirudo, *Sorig.*
,, serrifera, *Forbes*
,, Sorigneti, *Geinitz*
Cyphosoma radiatum, *Sorig.*
Discoidea Dixoni, *Forbes* (Fig. 66).
,, minima, *Ag.*
Galerites subrotundus, *Mant.* (Fig. 64).
Hemiaster minimus, *Ag.* (Fig. 65).
Holaster planus, *Mant.*
Micraster corbovis, *Forbes*
Salenia granulosa, *Forbes*

Actinozoa.—The only corals which have yet been found in the Middle Chalk, are *Axogaster cretacea* and *Parasmilia centralis,* and they are rare.

Spongida.—Sponges are rare in the lower beds, but become common at the top of the *Terebratulina* zone. The following include those which are of most general occurrence:—

Cephalites Benettiæ, *Mant.*
,, longitudinalis, *Smith*
Craticularia Fittoni, *Mant.*
Guettardia stellata, *Mich.*
Plocoscyphia convoluta, *Smith*
,, flexuosa, *Mant.*
Steletta inclusa, *Hinde*
Ventriculites alcyonoides, *Mant.*
,, decurrens, *Smith*
,, impressus, *Smith*
,, radiatus, *Mant.*

CHAPTER XXVII.

THE MIDDLE CHALK IN KENT.

1. THE COAST SECTION.

General Description.

As in the case of the Lower Chalk, we shall commence our description of the Middle Chalk with the section exposed in the Kentish cliffs near Dover, and once more we must refer to the excellent description of the chalk of these cliffs by W. Phillips in 1818, and to Mr. Whitaker's supplementary account in 1872. Those of Phillips's divisions now included in the Middle Chalk are as follow:—

Bed b.—Chalk with interspersed flints [lower part only].
Bed c.—Chalk with few flints, 130 feet thick.
Bed d.—Chalk without flints, but containing numerous thin beds of organic remains [? nodules] 90 feet.

He describes Bed "d" as yellowish and hard, but does not mention that the lowest part is harder than the upper; he does, however, say that the "thin beds of organic matter are nearly in contact in the lower part of the stratum, and are more separate in the upper part of it," a remark which clearly applies to the layers of yellowish nodular lumps. He also notes the quantity of shell fragments which are present—"a large proportion of them being varieties of the striated shell or Inoceramus." He also mentions that "Ammonites from 12 to 18 inches in diameter are not uncommon."

Mr. Whitaker notes that "this division, from its hardness, causes the overhanging profile at the lower part of Shakespeare's Cliff,* the underlying softer chalk being worn away from below it by the sea"; and he mentions that nearer Folkestone this lower massive part often falls in large blocks. This part represents the Melbourn Rock and Phillips's Bed "d" practically coincides with the modern zone of *Rhynchonella Cuvieri,* but the thickness given is about 20 feet too much.

Bed "c," described by Phillips as soft white chalk, is the *Terebratulina* zone, and it is a curious fact that when Mr. W. Hill studied the Middle Chalk of Dover in 1886 he placed its upper limit at exactly the same horizon, though he had not then read Phillips's account. In that account † it is stated that the "chalk with interspersed flints is separated from that with few flints by a bed of marl 2 or 3 inches thick"; further, that "about 20 feet below that bed two somewhat thicker beds of soft chalk marl run parallel with each other, and with the line of separation, and at about 3 feet apart." Lastly, beneath the topmost thin bed of marl "two thin beds of separate flints are very visible." The accuracy of this will be seen by comparing it with the vertical section given in the later paper referred to.[*]

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* Since Mr. Whitaker wrote, this portion of the cliff has fallen and no longer overhangs, though in time the erosion of the waves will doubtless produce a similar conformation.

† See Conybeare and Phillips, Geology of England and Wales, p. 99.

In 1874 Hébert published a detailed description of the Middle and Upper Chalk as seen near Dover.[†] This we shall have occasion to discuss further on, and need only here mention that he gives a table comparing his divisions with those of Phillips, and that his divisions are as follows:—

	Metres.
Craie à *Holaster planus*	8 or 12 [‡]
Inoceramus labiatus, divided into	
a. zone supérieur à *Rhynchonella Cuvieri* et *Inoceramus Brongniarti*	35[‡]
b. zone moyenne, craie noduleuse â *Am. nodosoides* and *Am. rusticus*	25
c. zone inférieure, craie argileuse â *Bel. plenus*	14

Professor Barrois in 1876 adopted Hébert's divisions, but made a somewhat different grouping, referring the zone of *Bel. plenus* (*c*) to the Cenomanian or Lower Chalk, calling the next division (*b*) the zone of *Inoceramus labiatus*, and (*a*) the zone of *Terebratulina gracilis*. These two zones, with that of *Holaster planus*, he grouped as Turonian.

In 1877 the lower part of the Middle Chalk as seen near Lydden Spout was described by Mr. F. G. H. Price,[||] who employed the old classification of Lower Chalk without flints and Upper Chalk with flints, so that his measurements ceased at the first line of flints. His Bed viii., which he calls the "grit-bed" or zone of *Cardiaster pygmœus*, is the lower 32 feet of Barrois' zone of *Inoc. labiatus* and his Bed ix. includes the rest of this zone and part of the zone of *Terebratulina gracilis*, with a thickness of 118 feet up to the first line of flints, which Mr. Price took as the base of the Upper Chalk.

In 1880 the Middle Chalk, as developed in Cambridgeshire, was defined and established,[¶] and in 1886 Mr. W. Hill studied the Middle Chalk of Dover and compared its sub-divisions with those established in Cambridgeshire.[**] In 1897 Mr. Hill re-examined the

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[*] On the Beds between the Upper and Lower Chalk of Dover, by W. Hill, Quart. Journ. Geol. Soc., Vol. xlii. p. 232 (1886).

[†] Comparaison de la Craie des côtes d'Angleterre avec celle de France, Bull. Soc. Géol. de France, Ser. 3, T. ii. p. 416.

[‡] These thicknesses are much too little. Hébert appears to have thought that the chalk at the base of the cliff east of Dover belonged to the top of the nodular chalk *à Am. nodosoides*, and so missed out about 70 feet.

[||] Quart. Journ. Geol. Soc., Vol. xxxiii. p. 431.

[¶] "On the Sub-division of the Chalk," by A. J. Jukes-Browne. Geol. Mag., Dec. II., Vol. vii., p. 248.

[**] William Hill, Quart. Journ. Geol. Soc., Vol. xlii. p. 232.

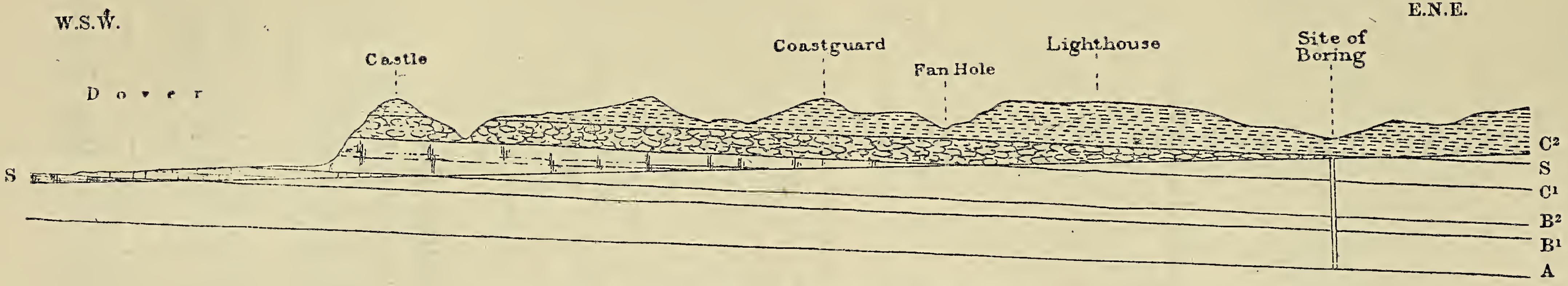

Fig. 67 —Section along the coast east of Dover.

Horizontal Scale, $1\frac{1}{2}$ inch to a mile. Vertical Scale 900 feet to an inch.

C^2 Zone of Micraster coranguinum.
C^1 Zones of M. cortestudinarium and H. planus.
B^2 Zone of Terebratulina.
B^1 Zone of Rhync. Cuvieri.
A. Lower Chalk.
SS. Sea level.

Dover cliffs for the purpose of revising his previous description and of fixing on the most convenient plane for the summit of this division.

Still more recently the two zones comprised in the Middle Chalk have been described by Dr. A. Rowe.*

The following account of the beds seen in these cliffs has been drawn up from Mr. Hill's paper and from his subsequent notes. The lower beds are most accessible by the cliff path at the western entrance of the tunnel through Shakespeare's Cliff (see Fig. 24, p. 35), and though the very highest part of the Middle Chalk occurs in this cliff, it is inaccessible, and the higher beds must be studied on the shore east of Dover (see Fig. 67).

Zone of Rhynchonella Cuvieri.

The lower part of this is the "Grit-bed" of Price, and is undoubtedly the equivalent of the *Melbourn Rock*, although it here attains a much greater thickness than in any other locality. The lower 12 feet consists of hard whitish nodular chalk streaked with veins of greyish marly material, while the upper 20 feet is yellowish and less compact, the nodular layers weathering out very conspicuously. In these respects it closely resembles the Melbourn Rock of the Midlands. *Discoidea minima* and *Cardiaster pygmæus* are the two commonest fossils, but *Galerites subrotundus* appears at the top of the bed.

Above the "grit-bed" there is rather hard yellowish chalk containing harder nodules, which are arranged in more or less definite layers, which, however, become more distant, and the chalk between becomes gradually softer in the higher part of the zone.

This nodular chalk extends for about 38 feet, giving by our measurements a total of 70 feet to the zone of *Rhynchonella Cuvieri*. This is rather less than the thickness assigned to the nodular chalk by Professor Hébert (his zone of *Ammonites nodosoides*), which was 82 feet, but it closely corresponds with the measurement of Mr. F. Drew, who found the "concretionary chalk" to be 73 feet thick.† *Rhynchonella Cuvieri* and *Inoceramus mytiloides* (= *labiatus*) are the prevalent fossils in this part of the zone.

The Terebratulina Zone.

This zone consists of dull white rather soft friable chalk, with many thin seams of greyish marl, and in the upper part it contains several layers of flint nodules, each at some distance from the other, except the two highest layers, which are near together. The total thickness is about 160 feet.

Above the highest well marked nodular layer, which is taken as the top of the underlying zone, the small Brachiopod *Terebratulina gracilis* var. *lata*, occurs abundantly both in Shakespeare's

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* Proc. Geol. Assoc., Vol. xvi., p. 315 (1900).

† In Whitaker's Geology of the London Basin, Mem. Geol. Survey, 1872, Vol. ix., p. 3 .

Cliff and on the east of Dover. Another frequent and characteristic fossil is *Inoceramus Cuvieri*, and in the upper beds *Micraster corbovis* and *Holaster planus* are not rare.

The first layer of flints occurs about 60 feet above the bed taken as the base of the zone, and very little more of the chalk can be reached by Shakespeare's Cliff, but above the entrance to the tunnel at Haycliff there is about 20 feet of chalk above this line of flints, and we believe that the chalk exposed above the beach at the eastern end of the town of Dover is very little, if at all, above that which forms the top of the cliff above the Haycliff Tunnel.

Near the base of this eastern cliff two well-marked seams of grey marl may be seen, the upper one containing some fossils and small embedded pebbles of chalk. About 16 feet above these is a layer of flints, succeded by about 30 feet of chalk, in which there are two discontinuous layers or lines of flints. Above this come two well-marked layers of argillaceous marl, separated by a bed of somewhat nodular chalk, with irregular greyish veinings 4 feet thick. In these beds *Terebratulina gracilis* var. *lata*, *Rhynchonella Cuvieri*, and *Inoceramus mytiloides* are common.

The upper layer of marl is succeeded by about 15 feet of whitish chalk with grey veinings, and near the top of this are two conspicuous layers of flints about 3 feet apart. Then comes another layer of grey marl, which is the bed taken by Phillips as the limit between his "chalk with few flints" and the "chalk with many flints"; this layer, too, was afterwards taken by one of us as the summit of the *Terebratulina* zone.* Now, however, we prefer to carry this zone about 16 feet higher up; the chalk above this marl band is soft and whitish, but it includes lumps of very hard crystalline chalk, which near the top become numerous, and have a tendency to arrangement in layers. This chalk contains some specimens of *Holaster planus*. It is succeeded by a bed about 4 feet thick, which is full of flints, and this we take as the base of the Upper Chalk. (See Fig. 68.)

Since the above was written Dr. Rowe has published an account of the Dover cliffs, with especial reference to the zonal distribution of the fossils.† His measurements of the distances between the marl-bands in the east cliff agree very nearly with ours, but he takes the upper limit of the zone at a seam of marl which is about 7 feet above the plane which we regard as the base of the zone of *Holaster planus*. The fact appears to be that the change from the fauna of one zone to that of the other takes place in this 7 feet of chalk; *Holaster planus* is fairly common in it, and though *Micrasters* are rare and *Echinocorys* does not seem to occur, we prefer to take the flint-bed as the top of the zone, because a similar but rather thinner bed of flints occurs in the inland sections, while the marl band is not recognisable inland.

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*W. Hill in Quart. Journ. Geol. Soc., Vol. xlii., p. 235 (1886).

† Proc. Geol. Assoc., Vol. xvi., p. 289 (1900).

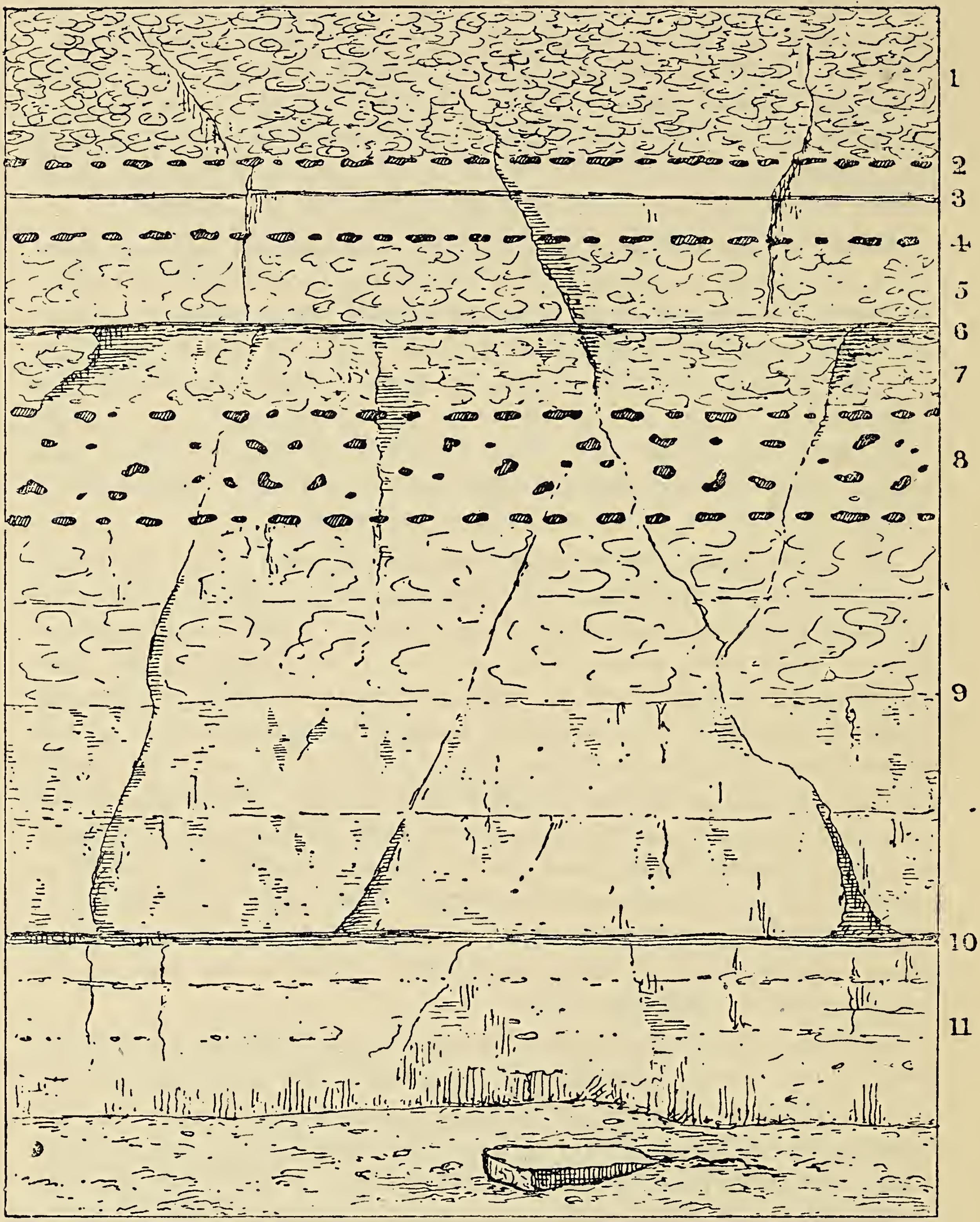

Fig. 68—View of a portion of the cliff east of Dover, showing the beds at the junction of the *Terebratulina* zone with that of *Holaster planus*. The numbers refer to the description given on p. 377

The following is an abstract of the section in the lower part of East Cliff, Dover:—

			ft.	in.
Zone of *H. planus.*	1	Rough nodular rocky chalk - - - - -	4	0
	2	Layer of flints - - - - - - -	0	4
	3	Smooth chalk with a seam of marl in the middle	2	8
	4	Layer of flints -- - - - - - - -	0	4
	5	Rough lumpy chalk - - - - - - -	3	0
	6	Seam of soft grey marl, forming an open crevice.		
	7	Rough lumpy chalk with *Holaster planus*- -	3	6
	8	Chalk with many flints - - - - -	4	0
Terebratulina Zone.	9	Soft white chalk enclosing lumps of hard chalk, which are most numerous in the upper part-	16	0
	10	Seam of grey marl forming an open crevice.		
	11	Soft white chalk - - - - - -	15	0
	12	Two layers of marl enclosing a band of chalk which is veined with grey marl - - -	4	0
	13	Soft white chalk with occasional flints - -	46	0
	14	Chalk with two seams of marl at the top -	10	0
			108	10

The numbers prefixed to the beds refer to those in Fig. 68.

FOSSILS FROM THE MIDDLE CHALK OF DOVER.

The following list of fossils from the Middle Chalk of Dover has been compiled from the lists given by Mr. W. Hill and Dr. A. W. Rowe in their respective papers above mentioned, the initial letters indicating by whom each species is recorded:—

-----	Zone of *Rh. Cuvieri.*	Zone of *Ter. gracilis.*
Pisces		
Beryx sp. - - - - - - - - - - -		H R
Corax falcatus, *Ag.* - - - - - -		H
Lamna appendiculata, *Ag.* - - - - - -	R	R
,, plicatella, *Reuss* - - - - - -	H	
Macropoma Mantelli, *Ag.* - - - - - -		H
Oxyrhina Mantelli, *Ag.* - - - - - - -		R
Ptychodus decurrens, *Ag.* - - - - - -	H	H
,, mammillaris, *Ag.* - - - - - -	R	R
,, polygyrus, *Ag.* - - - - - -	R	R
Scapanorhynchus subulatus, *Ag.* - - - - -	H	
Cephalopoda and Gasteropoda.		
Ammonites [Haploceras] catinus, *Mant.* - - -	R	
,, [Acanthoceras] Cunningtoni, *Sharpe* -	H R	
,, [,,] nodosoides, *Schlüter* -	H	
,, [Pachydiscus] peramplus, *Mant.* - -	R	R
Aporrhais sp. - - - - - - - -		R
Pleurotomaria perspectiva, *Mant.* - - - -		H R
Solariella (Turbo) gemmatus, *Sow.* - - - -		R

	Zone of *Rh. Cuvieri.*		Zone of *Ter. gracilis.*	
Lamellibranchiata.				
Inoceramus Brongniarti ? *Sow.*				R
,, Cuvieri, *Sow.*	H	R		R
,, Lamarcki, *Mant.*			H	
,, mytiloides, *Mant.*	H	R	H	R
,, sp.				R
Ostrea canaliculata, *Sow.*				R
,, hippopodium, *Nilss.*		R		R
,, normaniana, *d'Orb.*		R		R
,, semiplana, *Sow.*				R
,, vesicularis, *Lam.*	H	R	H	R
Pecten cretosus, *Defr.* (=nitidus, *Mant.*)		R		R
,, (Neithea) quinquecostatus, *Sow.*				R
Plicatula Barroisi, *Peron*				R
,, sigillina, *S. Woodw.*		R		R
Radiolites Mortoni, *Mant.*	H			
Spondylus dutempleanus, *d'Orb.*			H	R
,, latus *Sow.*		R	H	R
,, spinosus, *Sow.*		R	H	R
Brachiopoda.				
Crania egnabergensis, *Retz.*				R
Rhynchonella Cuvieri, *d'Orb.*	H	R	H	R
,, ,, var. (small and round)	H		H	
,, reedensis, *Eth.*		R		R
,, Woodwardi, *Dav.*				R
Terebratula semiglobosa, *Sow.*	H	R	H	R
Terebratulina gracilis, var. lata., *Eth*	H	R	H	R
,, striata, *Wahl.*	H	R	H	R
Crustacea and Annelida.				
Pollicipes striatus, *Darw.*			H	
Scalpellum maximum, *Sow.*				R
Serpula ampullacea, *Sow.*			H	R
,, fluctuata, *Sow.*				R
,, granulata, *Sow.*				R
,, ilium, *Sow.*			H	R
,, plana, *Woodw.*		R		R
,, plexus, *Sow.*	H			R
Echinodermata				
Bourgueticrinus sp.		R		R
Calliderma mosaicum, *Forbes*			H	
Cardiaster pygmæus, *Forbes*	H	R		R
Cidaris hirudo, *Sorig.*	H	R		R
,, perornata, *Forbes*		R		R
,, serrifera, *Forbes*		R	H	R
Cyphosoma magnificum, *Ag.*	H			
,, radiatum, *Sorig.*			H	R
Discoidea Dixoni, *Forbes*	H	R	H	R
,, minima, *Ag.*	H		H	
Galerites castanea, *Brongn.*	H			
,, globulus, *Desor*	H	R		
,, subrotundus, *Mant.*	H	R	H	R

	Zone of *Rh. Cuvieri.*	Zone of *Ter. gracilis.*
Glyphocyphus radiatus, *Hoening.*	R	
Hemiaster minimus, *Ag.*	R	H R
Holaster planus, *Mant.*	R	H R
„ placenta, *Ag.*	R	R
Micraster corbovis, *Forbes*	R	H R
„ Leskei, *Desm.*		H R
Ophiura sp.		R
Pentacrinus sp.	R	R
Salenia granulosa, *Forbes*	H R	R
Actinozoa.		
Axogaster cretacea, *Londs.*	H	
Parasmilia centralis, *Mant.*	R	H R
Spongida.		
Camerospongia capitata, *Smith*	R	R
Cephalites Benettiæ, *Mant.*	R	R
„ longitudinalis, *T. Smith*	R	R
Cliona cretacea, *Portl.*		R
Craticularia Fittoni, *Mant.*	R	R
Doryderma ramosum, *Mant.*	R	R
Guettardia stellata, *Mich.*	R	H R
Heterostinia obliqua, *Benett*	R	R
Pachinion scriptum, *Roemer*	R	R
Pharetrospongia Strahani, *Sollas*		R
Pholadocladia ramosa, *Hinde*		R
Plinthosella compacta, *Hinde*		R
Plocoscyphia convoluta, *Smith*	R	R
„ labrosa, *Smith*	R	R
Porosphæra globularis, *Phil.*	R	R
Ragadinia sulcata, *Hinde*		R
Siphonia Kœnigi, *Mant.*		R
Stelletta inclusa, *Hinde*		R
Stichophyma tumidum, *Hinde*		R
Ventriculites cribosus, *Phil.*	R	R
„ decurrens, *Smith*	R	R
„ impressus, *Smith*	R	H R
„ infundibuliformis, *Woodw.*		R
„ mammillaris, *Smith*	R	H R
„ radiatus, *Mant.*	R	R

2. The Inland Parts of Kent.

The base of the Middle Chalk is well defined inland in Kent by the hard rough nodular beds of the Melbourn Rock. This rock, known at Dover as the Grit Bed, rapidly diminishes in thickness from 32 to only 12 or 15 feet, and in quarries it generally presents the characteristic features of the Melbourn Rock of Cambridgeshire and Hertfordshire.

This rocky chalk is overlain by the firm white chalk of the zone of *Rhynchonella Cuvieri*, which is divided into courses of variable thickness by thin seams of marl; this gradually gives place to the massively bedded white chalk of the *Terebratulina* zone. In the upper part of the latter zone well marked layers of marl occur, like those at Dover, though the seams do not all appear to be at the same horizon ; flints also occur either as scattered nodules or in widely separated layers. In the highest part of the *Terebratulina* zone hard crystalline lumps occur, which frequently show the structure of *Ventriculites* or other sponges in iron stains.

Although many borings have been made through the Chalk of Kent, in no case have the well sinkers preserved a sufficient record of the characters of the different beds traversed to enable us to recognise with certainty the top and bottom of the Middle Chalk ; but it is probably over 200 feet thick, and if a boring at Sittingbourne recorded by Mr. W. Whitaker is correctly interpreted, it is there about 221 feet thick.*

The following is a brief account of the more important of the exposures seen along the outcrop of the Middle Chalk through Kent.

STRATIGRAPHICAL DETAILS.

All the following information was obtained by Mr. W. Hill, during a rapid survey of the outcrop in 1897. He did not visit such quarries and exposures as exist between Folkestone and Brabourne, as these are not likely to differ from the corresponding portions of the coast section, but took up the inland outcrop near Brabourne and the valley of the Wye.

The Melbourn Rock is not infrequently exposed along the base of the North Downs, but the upper part of the zone of *Rhynch. Cuvieri* is seldom seen. Nearly all the quarries which have been opened on the slope of the Downs between the Valley of the Wye and the western border of Kent are worked in the soft white chalk of the *Terebratulina* zone. Many are very large, but the chalk seems now to be used only in small quantities to make lime for local purposes. The chalk is massively bedded, featureless, and almost unfossiliferous, so that, although the quarries often exhibit fine sections, they are as a whole uninteresting.

Hard, rough nodular chalk with *Rhynchonella Cuvieri* can be seen in the field-way over the Downs from Newgate Scrubbs, east of Brabourne and a large quarry on Brabourne Down is opened in the lower part of the *Terebratulina* zone.

In the valley of the Wye a small quarry by the roadside, 330 yards north of the main entrance to Olantigh Towers, exposes hard rough chalk which is probably the top of the Melbourn Rock. Similar rock is seen again in a quarry 300 yards south of All Saints Church, at Boughton Court (see p. 48) ; and on White Hill, half a mile north of Boughton Corner, is a large quarry in the upper part of the *Terebratulina* zone. The chalk exposed here includes two marly layers and a bed with hard lumps or masses showing the structure of sponges in iron stains ; many large flints are also seen.

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* The Rochester Naturalist, Vol. iii., p. 60 (1901).

At Charing the large quarry north of the village shows 50 feet of firm white, massively-bedded chalk belonging to the lower part of the same zone; at the base of the quarry face is a marked nodule-bed which contained many lumps of iron pyrites; spines of *Cidaris serrifera* also occurred in it. *Rhynchonella Cuvieri* (small), *Terebratula semiglobosa,* and *Lima spinosa* were obtained throughout, but only two or three specimens of *Terebratulina gracilis* var. *lata* were found, and those in the upper part of the quarry. A few flints were seen at the top.

The Hart's Hill quarry, a little further west, is in chalk at a somewhat lower horizon, and probably touches the zone of *Rhync. Cuvieri.* In the lower part of the quarry *Galerites subrotundus* occurred; in the higher part there is a face of some 55 to 60 feet in white, softish, blocky chalk, a marl band and a few flints occurring quite at the summit.

A typical example of these practically disused quarries is that at Lenham Hill; the whole section was accessible in 1896, and was as follows:—

	feet.
Soil and rubble - - - - - - - - -	2
Much broken and rubbly chalk - - - - - - -	3–4
Firm white chalk in massive beds - - - - - -	20
Layer of grey marl with nodules of white chalk - -	0½
Rather soft white chalk in massive beds, containing *Terebratulina gracilis*, var. *lata* - - - - - -	50
About	75

The base of the Middle Chalk and its junction with the Belemnite marls is exposed in an excavation made for rifle butts, three-quarters of a mile E.S.E. of Hollingbourne, the section below the soil being as follows:—

		feet.
Melbourn Rock.	Hard smooth white bedded chalk, with *Inoceramus mytiloides* and *Rhynch. Cuvieri* -	4
	Rough nodular white chalk in two beds separated by a marly seam - - - -	1½
	Very hard cream-coloured nodular rock in beds, separated by marl seams - - -	3
	Rough white nodular rock - - - -	2
Belemnite Marls.	Smooth, somewhat marly, but firm white chalk - - - - - - - - -	1½
	Grey marl weathering into thin laminæ -	1
	Smooth grey marly chalk - - - -	2½
Greyish-white chalk with *Pecten Beaveri*, seen for - -		6
		21½

The Melbourn Rock is again exposed near Cobham Farm (see p. 48), and in the lane leading to Boarley.

A fine section through the greater part of the *Terebratulina* zone is to be seen in the large quarry at Hollingbourne Hill, which is worked in two levels; the highest part of the upper face as seen in 1896 was as follows:—

	feet.
Soil and rubble	1
Blocky, softish white chalk with a few flints	6
Layer of flints	0½
A course of hard lumps showing the structure of sponges in iron stains	1
Soft white chalk	4
A layer of grey marl	0½
White soft chalk with a very few scattered flint nodules	6

The section is here complicated by a fault and talus slope, but at a slightly lower level the continuing face showed 45 feet of soft white chalk with a few flints in its upper part. In the lower workings of this quarry about 65 feet of massively-bedded white chalk without flints is seen containing *Terebratulina gracilis* var. *lata* and *Inoceramus Cuvieri*; a well-marked layer of marl occurs 17 feet above the floor of the pit. The total depth must be over 140 feet.

The Deptling quarry has a vertical face of about 100 feet. The upper part of this was inaccessible at the time of our visit (1896), but a few flints could be seen for 30 feet below the summit of the quarry. The remaining 70 feet was in massively-bedded, soft white chalk with *Spondylus spinosus,* while *Galerites subrotundus* and *Rhynchonella Cuvieri* were obtained from the quarrymen.

A quarry near Harp Farm, three-quarters of a mile north of Boxley, and another by the lower Bell Inn expose the upper part of the same zone with its usual characters.

The Melbourn Rock, with from 20 to 30 feet of the overlying chalk, is exposed in most of the quarries in the valley of the Medway. The section in the lower quarry of the Burham Brick Company has already been given (see p. 49); the base of the *Terebratulina* zone is probably just below the floor of the upper quarry, which continues the section through that zone and through the chalk with *Holaster planus.* The section will be given in Vol. III.

The section seen in Messrs. Peter's quarry at Wouldham has been given on a previous page (p. 49), and we need only remark that the Melbourn Rock, here about 12½ feet thick, is very well shown, covered only by 8 or 10 feet of firm whitish chalk.

The topmost beds of the Middle Chalk containing some scattered flints and three or four horizons along which flints occur in line at intervals, can be seen in the large quarry known as Bores Hole, south-west of Chatham, but the height which can be actually examined depends upon the quarrying operations, for the face exposed is sometimes vertical and inaccessible.

Passing westward to Wrotham two large quarries will be found on the slope of the hill N.N.E. of the village, and these form an almost continuous section, the lower one being entirely in the soft, massively-bedded, white chalk of the *Terebratulina* zone, while the other continues the section upward into the Upper Chalk.

The Melbourn Rock can be seen in the railway cutting north of Otford Station, but is much broken up, and the section is now somewhat obscure. It was clearer when seen prior to 1871 by Mr. Whitaker, who gave some account of it in 1872, with a sketch which is here reproduced.*

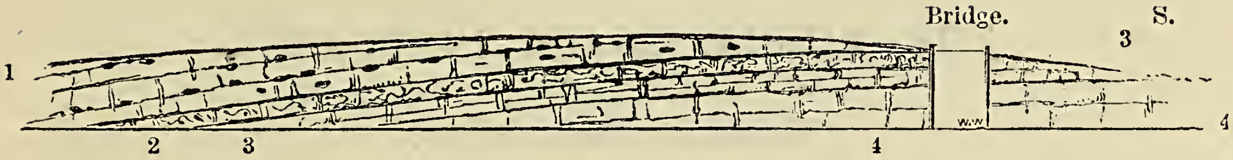

FIG. 69.—Cutting on the Sevenoaks Branch of the London Chatham and Dover Railway half a mile S.E. of Shoreham.

Middle Chalk. 1. Bedded chalk and upper part of the Melbourn Rock.
2. Lower part of the Melbourn Rock, 5 feet thick.

Lower Chalk. 3. Belemnite marls, "grey chalk rather clayey, 6 feet," passing down into lighter grey chalk (No. 4).

A small quarry just west of Chevening Park, and another 300 yards north-west of Court Lodge Farm, near Westerham, also expose the Melbourn Rock.

The quarry at Westerham Hill is in the *Terebratulina* zone and must be near the top of the zone, for three well-marked layers of flint are seen here, two near the bottom, and one high in the face, which exposes about 35 feet of soft white chalk.

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*Memoirs of the Geological Survey, Vol. iv. p. 25.

CHAPTER XXVIII.

THE MIDDLE CHALK IN SURREY.

GENERAL DESCRIPTION.

The Middle Chalk of Surrey is similar to that of West Kent. It has a well-marked band of Melbourn Rock at the base with a thickness of 12 to 14 feet. This is succeeded by the firm and rather rough chalk which forms the rest of the *Rhynchonella Cuvieri* zone, and this by the softer and whiter chalk of the *Terebratulina* zone. Above this the chalk becomes irregular and lumpy, a character which, as in Kent, is associated with a great increase in the number of flints, and with the occurrence of the fossil *Holaster planus*.

The total thickness of the Middle Chalk along the outcrop in Surrey is probably over 200 feet, but there is no continuous section through it, and the high dips make it difficult to estimate its thickness.

The deep borings in the London basin do not afford very satisfactory accounts of the Middle Chalk, for the particulars given are chiefly from the notes of foremen well-sinkers, and few specimens have been examined by geologists. At Streatham the thickness of the Middle Chalk is given by Mr. Whitaker* as 219 feet, but from Mr. Hill's notes of the specimens printed in the same memoir I gather that the Melbourn Rock is probably represented by the 10½ feet between the depths of 682 and 692½ feet, while the base of the *Hol. planus* zone may be a few feet below the depth of 463 feet; hence the thickness of Middle Chalk indicated by the Streatham boring is probably from 222 to 225 feet.

At Richmond the division appears to be much thinner, the lower zones, including the Melbourn Rock, being only about 150 feet thick, surmounted by a hard nodular rock of the western Chalk Rock type.

In the boring at Winkfield, near Windsor, the thickness of this part of the chalk appears to be 169 feet, including 14 feet of Melbourn Rock.

STRATIGRAPHICAL DETAILS.

The following account of exposures in Surrey is based on notes taken by Mr. W. Hill during a traverse made in 1897, to which are added quotations from those of previous observers.

Zone of Rhynchonella Cuvieri.

Melbourn Rock is exposed in the cutting at the north entrance of the tunnel between Warlingham and Oxted; a view of this is given on p. 54. Here the first 5 feet above the Belemnite Marls is hard nodular chalk, weathering along marly veins into a loose rough rubble, and above this are layers of hard nodular rock of yellowish-grey colour, separated by courses of smoother but hard chalk. The succeeding beds to the north are firm and somewhat rough but pass up into smoother white chalk. *Inoceramus mytiloides* and *Rhynchonella. Cuvieri* are common fossils.

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* Geology of London, Vol. ii. p. 225 (1889).

The large quarry at the Oxted Lime Works also exposes the Melbourn Rock and some 30 feet of the *Rhynchonella Cuvieri* zone.

After passing through a long tunnel, the railway from Oxted to Croydon is carried through a series of cuttings, and the first seven of these are cut through the zones of *Rhynchonella Cuvieri* and *Terebratulina* The sections along this line of rail were described by Mr. Caleb Evans soon after they were made, and the following are extracts from his account.*

The deepest part of the first cutting is at the northern end of the tunnel, where he states it to be 34 feet. From the section at the end of the paper, the beds there exposed seem to have been as follow :—

	ft.	in.
Rubbly chalk - - - - - - - - - -	15	0
Band of yellowish marl.		
Chalk with marly parting at base - - - -	2	0
Chalk with *Inoceramus mytiloides* - - - -	4	0
Chalk - - - - - - - - - - -	6	0
Marly parting with brown earth, *Inoceramus.*		
Chalk - - - - - - - - - - -	1	10
Parting of brown marl with *Inoceramus* (shell).		
Chalk with marly parting in the middle - - -	5	5
	34	3

He describes the 4-foot bed as crowded with fragments of *Inoceramus* shells, together with some that are entire. "On the banks the casts of large *Ammonites* are occasionally met with . . . these approach nearest to *Am. peramplus* of Mantell." From this cutting, which he numbered XIII., he obtained some other fossils but none from the next (No. XII.).

The succeeding cuttings (Nos. XI., X., IX., VIII., and VII.) traverse white chalk with a few flints and occasional layers of marl; these were called the Whiteleaf Beds by Mr. Evans, and correspond with our *Terebratulina* zone. In cutting No. IX. he mentions "a bed of a nodular and concretionary character with ochreous marking, apparently the remains of sponges. *Galerites subrotundus* and *Inoceramus Brongniarti* are the prevalent fossils."

Returning to the escarpment, the Melbourn Rock and some 20 feet or 30 feet of the chalk above it is exposed in the quarry near Caterham Station, and again in that by Merstham Station. At Farrington's Lime Works, near Reigate, the Melbourn Rock is seen nearly two-thirds up the face of the quarry, with about 40 feet of the over-lying chalk; this, however, was not accessible at the time of our visit. At the Buckland Lime Works, it is just seen at the top of the quarry.

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* Geol. Assoc., Separate Paper (1870).

The large quarry of the Dorking Grey Stone Company at Betchworth has already been alluded to (p. 55); it shows a clear section through the zone of *Rhynchonella Cuvieri* and the upper part of the Lower Chalk, the following measurements being taken in 1897:—

			ft.	in.
Zone of Rhync. Cuvieri.		Soil and rubble - - - - - - -	4	0
		White chalk, firm, in massive courses (*Galerites subrotundus*), the upper part not accessible, but thickness estimated at - -	35	0
		Rather rough hardish chalk, veined with greenish grey - - - - - - -	6	0
		Seam of soft green grey marl containing hard whitish nodules - - - - - -	0	6
		Hard rough chalk hardly nodular, veined and streaked with greenish grey, *Inoceramus mytiloides*, *Rhynchonella Cuvieri*, *Terebratula semiglobosa* - - - - - - -	11	0
	Melb. Rock.	Hard rough nodular chalk creamy white, in massive well defined courses - -	8	0
		Very hard creamy white nodular rock weathering into thin irregular courses marked by seams of greenish grey marl	2	9
		A massive course of smooth very hard white rock marked with greenish grey veins -	3	0
Lower Chalk.		Buffish grey marly chalk, in platy layers - -	1	0
		Pale buff grey marly chalk, almost massive in bedding, passing rapidly at its base to white chalk - - - - - - - -	9	0
		White firm chalk - - - - seen for	50	0
			130	3

The Melbourn Rock is also seen at the top of the quarry at the old Dorking Lime Works, in the Milton Court chalk-pit about a mile farther west, and in several small quarries between this and Gomshall.

About a mile west of Shere, along the main road towards Guildford, it is seen again in a small roadside quarry, and it is also shown in two quarries about 300 yards south of the road half a mile and one mile respectively nearer Guildford.

West of Guildford the Rock is seen in a small quarry 200 yards north of Down Farm, and again in one or two disused pits north of Seale.

In the upper pit at the Victory quarries, three miles east of Farnham, the top of the Melbourn Rock and some of *Rhynchonella Cuvieri* zone is well shown. This quarry exposes nearly all the Middle Chalk, but the high dip and the irregular way in which it is worked makes it difficult to obtain satisfactory measurements.

The Terebratulina Zone.

The chalk of this zone shows no variation from that in Kent.

The large quarry near the Rose and Crown Inn, four miles south of Croydon, exposes more than 70 feet of chalk in the upper part of the zone overlain by nodular chalk with flints (zone of *H. planus*). This quarry is mentioned by Mr. Whitaker* in his Geology of the London Basin.

A mile further south, close to the Croydon and Oxted railway line, is a large quarry at Whiteleaf. About 70 feet to 80 feet of massively-bedded chalk is seen here. The lower part is firm white chalk, and is perhaps the highest part of the zone of *Rhynchonella Cuvieri*, for that fossil occurs with *Galerites subrotundus*; the upper part is softer, but is without flints; in this *Spondylus spinosa* is a common fossil. This chalk is included in the Whiteleaf beds of Mr. Caleb Evans.†

The middle part of the zone is exposed in a quarry about 1½ mile E.N.E. of Gomshall, and much of the chalk of this zone is exposed at intervals in a lane cutting leading up White Down from White Down Brickyard.

The *Terebratulina* chalk is again exposed in the upper part of the large quarry at Betchworth, and in 1897 Mr. W. P. D. Stebbing described two boulders of granitoid rock which are stated to have come from the *Terebratulina* zone in this quarry.‡ Both were much broken before they came into his hands, and were found after a blast. The larger fragment weighed 7 lb. 7 oz., and consists of a fine-grained granite, which is very much decomposed; it bears the remains of several lower valves of *Spondylus latus* and some *Serpulæ*. The other fragment appeared to be half of an ovoid mass, and weighed 3 lb. 12 oz. It is less decomposed and is a granite of coarser grain, and contains much white mica.

The upper part of this zone is also seen in the "Echo pit," about a mile S.E. of Guildford; and again in the Shalford quarries south of Guildford, where the section seen in 1897 was as follows:—

	ft.	in.
Soil, etc. - - - - - - - - - - - -	1	0
Broken chalk, rubbly - - - - - - - - -	2	0
A layer of flints - - - - - - - - - - -	0	6
Rather rough lumpy chalk passing down into smooth white chalk, including a course of hard iron stained lumpy chalk. A few flints occur - - - - -	20	0
Smooth white, but firm chalk in courses 2 or 3 feet thick marked by thin marl seams - - - - -	10	0
A course of hard rough lumpy chalk showing structure of sponges and ventriculites in iron stains -	1	3
Firm, almost hard, rather lumpy chalk with a few finger like flints - - - - - - - - -	4	6
Firm white chalk - - - - - - - - -	9	0
Marl band - - - - - - - - - - - -	0	4
Massively bedded white softish chalk seen for - -	20	0

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*Geology of the London Basin, W. Whitaker, 1872, Vol. i., p. 22 (from Mr. Drew's notes).

† On some Sections of Chalk between Croydon and Oxted, Geologists' Assoc., 1870, p. 17.

‡ See Quart. Journ. Geol. Soc. Vol. liii. p. 213 (1897).

The quarry at Monkshatch, 4 miles west of Guildford, also shows the upper part of this zone, and still farther west the whole of it must be exposed in the Victory quarry 3 miles east of Farnham.

FOSSILS FROM THE MIDDLE CHALK OF SURREY.

(Chiefly from Mr. Evans's Lists.)

	Zone of Rhynch. Cuvieri.	Zone of Ter. gracilis.
Ammonites [Pachydiscus] peramplus, *Mant.*	x	–
Turbo ?	–	x
Inoceramus Brongniarti, *Sow.* (? Cuvieri)	x	x
,, mytiloides, *Sow.*	x	x
,, striatus, *Sow.*		–
Ostrea vesicularis, *Lam.*	x	–
,, semiplana, *Mant.*	x	–
Spondylus spinosus *Sow.*	x	–
,, latus, *Sow.*	x	–
Terebratula semiglobosa, *Sow.*	x	x
Rhynchonella Cuvieri, *d'Orb.*	x	–
,, Mantelliana ? *Sow.*	–	x
,, plicatilis, *Sow.*	x	–
Terebratulina gracilis, *Schloth.* var. lata, *Eth.*	–	x
,, striata, *Wahl.*	x	–
Cyphosoma sp.	–	x
Discoidea subuculus, *Klein* (? Dixoni)	x	x
Galerites castanea, *Brongn.*	x	–
,, subrotundus, *Mant.*	–	x
Enoploclytia Leachi, *Mant.*	–	x
Camerospongia campanulata, *Smith*	–	x
Plocoscyphia sp.	–	x
Ventriculites cavatus ? *Smith*	–	x
,, radiatus, *Smith*	–	x

CHAPTER XXIX.

THE MIDDLE CHALK IN HAMPSHIRE.

General Description.

The Middle Chalk of Hampshire bridges the broad uplift of the Weald, and unites the outcrop which we have traced along the North Downs to that which occupies a similar position in the escarpment of the South Downs.

As the mass of the Middle Chalk passes from Surrey into Hants the beds lose their northerly dip and receive a gentle tilt or inclination towards the west, in consequence of which the basset surface widens out, so that west of Alton and Selborne it occupies a considerable area of land. Further south it is somewhat narrowed but expands again in the valley of West Meon.

Besides this continuous tract of outcrop there are three other areas in the county where Middle Chalk comes to the surface, these are—(1) near Winchester (2) the Vale of Kingsclere, and (3) several irregular inliers between the last and the Vale of Pewsey. The Winchester inlier is due to a cross roll causing an upward bulge or dome on the prolongation of the anticline which runs through Pulborough and West Meon. The northern inliers mark out the course of the northern branch of the Wealden uplift, and their isolation is doubtless due to a series of cross rolls or transverse undulations from north to south, producing troughs or basins in which a greater or less thickness of Upper Chalk is brought in. If it were not for these local depressions or synclines the outcrops of the Upper Greensand and Lower Chalk would have been continuous from the Vale of Pewsey to the north-western border of the Wealden area.

The Melbourn Rock occurs throughout the county, and has the same characters as in Surrey, so that there is no difficulty in following its outcrop. The zones of *Rhynchonella Cuvieri* and of *Terebratulina* succeed in usual course, but along the eastern outcrop great difficulty was experienced in trying to trace the zone of *Holaster planus* which does not seem to be represented by anything like the Chalk Rock.

Near Winchester, however, nodular chalk with *Holaster planus* is fairly well exposed at several points, and was first oberved by Professor Barrois.*

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* Recherches sur le terr. Crét. Sup., 1876, p. 41.

In the north-western part of the county beds of the true Chalk Rock type are found, and made it easy to draw a line for the base of Upper Chalk round the Vale of Kingsclere and the other inliers above mentioned.

The thickness of chalk between the Melbourn Rock and the Chalk Rock near Winchester, appears to be nearly 200 feet, and in all probability that is about its thickness along the main outcrop in the eastern part of the county. In the Vale of Kingsclere it does not seem to be more than 150 feet. Near Warminster, in Wiltshire, it is barely 100 feet thick. Thus the Middle Chalk appears to diminish somewhat rapidly westward.

STRATIGRAPHICAL DETAILS.

A. SECTIONS ALONG THE MAIN OUTCROP.

Zone of Rhynchonella Cuvieri.

Mr. Hill found *Rhynchonella Cuvieri* and *Inoceramus mytiloides* in a small quarry two-thirds of a mile N.N.W. of Bury Court, near Bentley. There is also a quarry in hard massive chalk north of Lower Froyle, which may be in this zone.

The Melbourn Rock and some of the overlying chalk, with *Inoceramus mytiloides* and other fossils, are well exposed in the railway-cutting south-east of Alton, and also in the quarry less than half a mile to the east just above the contour line of 400 feet. These exposures are in an outlier, and there is another smaller one on the hill east of Chawton House.

The main outcrop passes west of Alton, Chawton, and Farringdon, and then spreads out over the high ground between Tisted and Newton Valence and thence eastward to Selborne Hill. It runs out again on to Noar Hill to the south of Selborne, where there are several large old quarries from which much chalk must have been taken in former years probably for burning to lime.

South-west of Hawkley the outcrop of this zone becomes very narrow and is confined to the steep escarpment which terminated in the bold promontory of Wheatham Hill. Here the boundary lines drawn by Mr. Hawkins for the base and summit of the Middle Chalk are about 180 feet apart.

West of Ramsdean the beds come within the influence of the Petersfield anticline; the outcrop of the Melbourn Rock passes to the north of East Meon, and thence south-westward for some distance, returning along the southern border of the Meon valley to the hills above Buriton.

The Terebratulina Zone.

Mr. Hill identified the zone of *Terebratulina* in a quarry by Glade Farm, about a mile and a quarter north of Bentley.

Professor Barrois (Recherches, p. 45) writes that the junction of Cenomanian and Turonian is seen to the north of Lower Froyle, and that the nodular chalk is overlain by a soft white chalk from which he obtained *Galerites subrotundus*. There are two quarries in the position indicated, the first showing hard white massive chalk, which is doubtless Lower Chalk and just below the horizon of the Belemnite marl, which marl, with some of the Melbourn Rock, may well have been visible on the eastern side of the pit. The other quarry at a higher level is in the *Terebratulina* zone.

The chalk of this zone runs along the slope of the hills north-west of Alton, and may be seen in two small quarries, one by the roadside half a mile north of Alton Church, and in another about the same distance north-west of the church, both in soft white chalk without flints.

South of Alton it runs to the west of Chawton and Farringdon, and through East Tilstead, and is exposed between the two latter places in a pit south of Marylane copse.

South-west of Selborne the *Terebratulina* zone occupies a considerable area, but near Hawkley it is contracted to a narrow outcrop on the slope of a steep escarpment. West of Langrish and Ramsdean it comes within the influence of the Petersfield anticline, and running up the Bordean Valley is exposed in a quarry south-west of Lower Bordean. The upper boundary passes by Drayton north-west of East Meon, and thence for a considerable distance down the valley which opens westward from Combe near East Meon; thence it returns along the slopes of the hills which run into the range of the South Downs.

B. Sections in the Winchester Inlier.

The inlying tract of Turonian near Winchester is not of large extent. It surrounds the small area of Lower Chalk mentioned on page 62, and extends also for a short distance on the western side of the valley of the Itchen. Dips of 5 or 6 deg. carry it rapidly beneath the Upper Chalk to the north and south of the anticlinal axis. The existence of this pericline appears to have been first indicated by Professor Barrois.*

Zone of Rhynchonella Cuvieri.

This zone is well exposed in the large quarry at Chilcombe (see p. 62). Mr. Ch. Griffith, of Winchester, informs us that the Melbourn Rock, " nodular and very hard, passes up into hard chalk with nodular layers and some marly bands; many of the beds are thick and massive, and break out in large blocks with curved surfaces, of a yellowish-grey colour when moist."

There is another pit in the same chalk on the Portsmouth Road south of Bar End. It is also exposed in the Goods Yard of the Great Western Railway. From these exposures the members of the Winchester College Natural History College have obtained the fossils indicated in the list on p. 394.

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* Recherches sur le Terrain Crétacé Supérieur, Mem. Soc. Géol. Nord, 1876 p. 40.

Terebratulina Zone.

The best section in this zone near Winchester is a large quarry on the southern slope of St. Giles' Hill east of the town. The following is a translation of the description of it given by Professor Barrois in 1876, reversed so as to read from above downwards:—

	feet.
Very nodular chalk, with *Rhynchonella Cuvieri*, *Terebratula* and *Spondylus spinosus*	10
Argillaceous marl	0½
Compact white chalk, with marl seams, nodular layers, and a few flints in irregular layers; *Terebratulina gracilis*, var. *lata*, *Ter. semiglobosa*, *Inoceramus Brongniarti*, *Spondylus spinosus*, and *Sp. latus*	26
Layer of hard yellow nodules	0½
Compact white chalk with marl seams, *Ter. gracilis*, var. *lata*	10
Layer of flints.	
Compact white chalk	5
Layer of flints.	
Firm compact white chalk, in beds separated by seams of shaly grey marl; contains a few small scattered flints	20
About	72

For the following remarks we are indebted to Mr. Griffith, who writes, "the chalk in this pit is massive and close grained, the beds dipping to the north at 5 deg. About half way up the face of the pit several large Ammonites were visible in 1896 along one definite line. There are four well marked layers of flint-nodules, black inside with thin rinds; and there are two rust-coloured nodular layers in the higher part. This chalk is used in building for interior work, and is also burnt for lime."

C. SECTIONS IN THE KINGSCLERE AND HURSTBOURNE INLIERS.

The Middle Chalk forms a cincture round the inlier of Kingsclere and Burghclere, and portions of it are brought to the surface again in the valleys to the westward, especially in the tributary valleys of the Bourne River from Combe and Verulam Dean to Hurstbourne Farrant and St. Mary Bourne. (See Fig. 70). The following notes on this district are furnished by Mr. F. J. Bennett.

The Melbourn Rock is traceable all round the Vale of Kingsclere; its base is exposed in a small pit less than three-quarters of a mile south-west of Sydmonton Church. The rock is more fully seen in the railway-cutting about a mile south of Burghclere, and its upper beds here contain fossils. The next cutting to the southward is in the soft white chalk of the higher zone, with occasional flints, *Ter. gracilis*, var. *lata*, and *Terebratula semiglobosa* occurring here.

Parts of both zones are exposed in a chalk pit by the side of the road two-thirds of a mile north of Sydmonton; near the bottom is massive chalk with veinings of greenish marl probably not far above the Melbourn Rock; this is overlain by 20 feet or more of broken chalk. The beds are dipping steeply to the north.

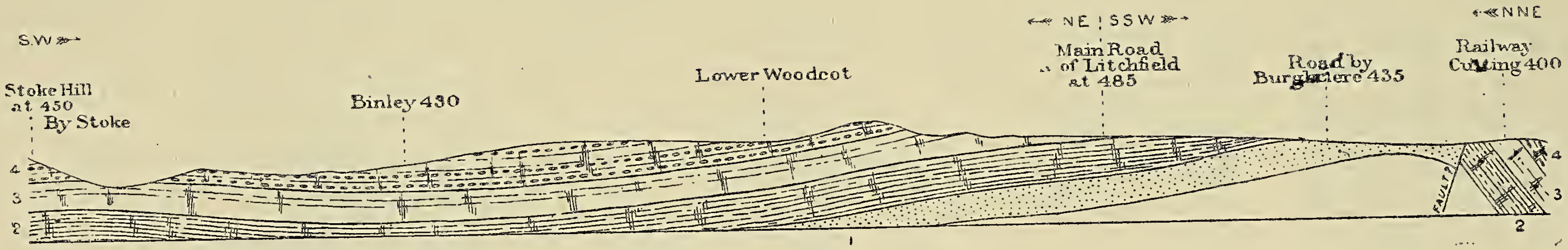

FIG. 70.—Section through Burghclere to Stoke Hill, near Hurstbourne.

Hor. Scale, one inch to a mile. Vert. Scale, 1400 feet to an inch.

4. Upper Chalk.
3. Middle Chalk.
2. Lower Chalk.
1. Selbornian.

The following list of fossils from the Middle Chalk of Hampshire has been compiled from the following sources:—

(1) A list of the species found in the neighbourhood of Winchester by the members of the Winchester College Natural History Society, drawn up and communicated by Mr. Ch. Griffith and Mr. R. M. Brydone. (w in the list.)

(2) List of the fossils obtained by Mr. J. Rhodes from the exposures in the Vale of Kingsclere. These were determined by Messrs. Sharman and Newton. (c in the list.)

(3) The list given by Mr. Westlake, in Dr. Stevens' History of St. Mary Bourne, of fossils found by him at Stoke Hill. (s in the list.)

List of Fossils from the Middle Chalk of Hampshire.

———	Zone of Rhync. Cuvieri.	Zone of Ter. gracilis.
Pisces.		
Belonostomus cinctus, *Ag.*		s
Beryx (Ctenothrissa) radians, *Ag.*		w s
,, sp.		s
Corax heterodon *Reuss* (=C. falcatus, *Ag.*)	w	w s
,, pristodontus, *Ag.*	w	
Lamna appendiculata, *Ag.*		w
,, obliqua (?=L. appendiculata, *Ag.*)	w	s
Macropoma Mantelli *Ag.*	w	s
Oxyrhina Mantelli, *Ag.*	w	w
Protosphyræna ferox, *Leidy*	w	w
Ptychodus decurrens, *Ag.*	w	w
,, mammillaris, *Ag.*	w	
,, polygyrus, *Ag.*		w
,, (a fin ray of)		s
Gyrodus cretaceus, *Ag.*	w	
Scapanorhynchus raphiodon, *Ag.*		w
Cephalopoda.		
Ammonites [Acanthoceras] Cunningtoni, *Sharpe*	w	
,, [Haploceras] lewesiensis, *Mant.*	w	
,, [Acanthoceras] Mantelli ? *Sow.*	w	
,, [,,] navicularis, *Mant.*	w	
,, [Prionocyclus] Neptuni, *Geinitz*		w
,, [Pachydiscus] peramplus, *Mant.*	w	s
,, [Acanthoceras] sussexiensis, *Mant.*	w	
,, [,,] large sp.		w
Baculites bohemicus, *Fritsch*	w	
Scaphites sp.	w	
Nautilus sublævigatus, *d'Orb*	w	
Gasteropoda.		
Natica vulgaris ? *Reuss*		s
Pleurotomaria perspectiva, *Mant.*		w
Lamellibranchiata.		
Inoceramus Brongniarti, *Sow.*	w	w s
,, *cf.* cuneiformis, *d'Orb.*		s
,, Lamarcki, *Park.*	w	w
,, mytiloides, *Sow.*	w	w
,, undulatus ? *Mant.*	w	

	Zone of Rhync. Cuvieri.	Zone of Ter. gracilis.
Lima subabrupta, *d'Orb.*		w
Ostrea normaniana, *d'Orb.*	c	w
,, vesicularis, *Lam.*	w	w s
Pecten sp.		w
Plicatula sigillina, *Woodw.*	w	w
Spondylus dutempleanus, *d'Orb.*		w
,, latus, *Sow.*	w	w
,, spinosus, *Sow.*		w
Teredo amphisbæna, *Goldf.*	w	w
Brachiopoda.		
Rhynchonella Cuvieri, *d'Orb.*	w c	w
,, plicatilis, *Sow.*	w c	w s
,, reedensis *Eth.*	w	w
Terebratula semiglobosa, *Sow.*	w c	w c s
Terebratulina gracilis, *Schloth.* var. lata, *Eth.*		w c
,, striata, *Wahl.*	w c	w
Crustacea.		
Enoploclytia Leachi, *Bell*		w
Palæastacus Dixoni, *Bell*		s
Annelida.		
Serpula annulata, *Reuss*		w
,, fluctuata, *Sow.*		w
,, plexus, *Sow.* (=gordialis)		w
Echinodermata.		
Bourgueticrinus sp.		w
Cardiaster pygmæus, *Forbes*	w	
Cidaris hirudo, *Sorig.*	w	
,, serrifera, *Forbes*	w	
,, Sorigneti ? *Gein.*		w
Cyphosoma radiatum, *Sorig.*		w
,, sp.		w
Discoidea minima, *Ag.*	w	w
,, Dixoni, *Forbes*	c	
Galerites subrotundus, *Mant.*	w	w
Holaster planus, *Mant.*		w ? s
Metopaster Parkinsoni, *Forbes*		w
Micraster Leskei ? *Desm.*		w
Peltastes Wiltshirei, *Wright*		s
Actinozoa.		
Micrabacia sp.		c
Spongida.		
Camerospongia subrotunda, *Mant.*	w	
Porosphæra globularis, *Phil.*		w
Siphonia Kœnigi, *Mant.*		w
Ventriculites alcyonoides, *Mant.*		w
,, infundibuliformis, *Woodw.*		w
,, radiatus, *Mant.*		w
,, sp.	w	

CHAPTER XXX.

THE MIDDLE CHALK IN SUSSEX.

General Description.

The Chalk of Sussex was described in a general manner by Mantell, Dixon, and others, and many of the fossils which they so diligently collected must have come from the fine sections of Middle Chalk which exist in this county. But unfortunately they lived before the time when definite divisions or stages had been established in the Chalk of England, so that, except in a few cases where particular quarries are mentioned, there is no knowing which of their fossils were obtained from the Middle Chalk.

Should any question arise, however, with respect to the exact horizon of certain of Mantell's types it might be possible to determine this by a microscopical examination of the matrix. Meantime, many of the old quarries are still open, and there are still collectors of Chalk fossils in Sussex; on them we would earnestly impress the necessity of recording the exact locality and horizon of every fossil they get, for without such a record such specimens are of little scientific value. Professor Ch. Barrois[*] was the first to give any adequate account of the Middle Chalk of Sussex, for he not only defined and described the several zones in the cliff section at and near Beachy Head, but he also visited the principal quarries near Lewes and those at Houghton in the Arun valley. From the fossils he collected at these places he came to the conclusion that most of the large series of Fish-remains from the Chalk studied by Mantell and Agassiz were obtained from the zones of the Middle or Turonian Chalk.

About the same time the late Rev. H. E. Maddock, formerly of Eastbourne, collected diligently from the successive zones of the coast section, and he kindly placed his lists at our disposal.

In 1884 Mr. C. Reid revised the Chalk and Tertiary areas of Sussex for the Geological Survey, tracing the boundary line of the Melbourn Rock and of the nodular chalk of the *Holaster planus* zone along the whole length of the South Downs. Some of the information then obtained by him has been published in the Explanations of the Eastbourne and Chichester sheets of the Geological Survey,[†] and a few of his notes on other inland exposures have been incorporated in the following account.

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[*] Recherches sur le Terrain Crétacé, pp. 16, 28, 33, etc. (1876).

[†] The Geology of Eastbourne, Mem. Geol. Survey (1898), and Geology of the country around Chichester (1902).

In 1895 Mr. Rhodes, the fossil collector of the Survey, was sent to collect from the fine series of sections near Lewes, zone by zone, so that we might possess more complete data with respect to the distribution of fossils at that locality.

Lastly, in 1896 and 1897 Mr. W. Hill carefully examined and measured the coast section near Beachy Head, and also visited some of the inland sections, for the purpose of forming an opinion on certain questions that had arisen.

The following account is drawn up principally from Mr. Hill's observations and measurements, supplemented by the information obtained by the observers above mentioned.

As Sussex possesses a good cliff section we have thought it desirable to commence with a description of this, and afterwards to give some account of the more important inland sections, as they are met with in going westward.

1. THE COAST SECTION.

The cliffs between Eastbourne and Beachy Head exhibit a complete section through the Middle Chalk, and every part of it can be examined either in or below the large quarries at Holywell, or in the cliffs west of Beachy Head Coastguard Station, where the dip carries each bed successively below the level of the beach. The following account is from notes taken by Mr. Hill:—

At Holywell Bay the Melbourn Rock is but a few feet above the level of the shingle, while the highest part of the quarry exposes the lumpy chalk lying just below the *Holaster planus* zone. At Holywell the Melbourn Rock is about 23 feet thick; its lower part consists chiefly of hard whitish nodular and rocky chalk in regular courses from one to two feet thick, separated by seams of marl, but there are two courses of nearly smooth homogeneous chalk; the upper part is in more massive beds of hard yellowish chalk, with layers of very hard, cream-coloured nodules. This rocky chalk passes up into less hard chalk with only a few layers of nodules, but still rather rough, and yellowish or creamy in tint, and containing numerous fragments of Inoceramus-shell. *Inoceramus mytiloides* is abundant in these beds, but *Rhynchonella Cuvieri* is much less common; their thickness is about 60 feet, which, with the 23 feet of Melbourn Rock, gives 83 feet for the zone of *Rhynch. Cuvieri.*

This shelly chalk gives place somewhat abruptly to the softer, whiter, and more massively-bedded chalk of the *Terebratulina* zone, which has here a thickness of about 133 feet, but in the upper 12 or 15 feet it becomes lumpy and uneven in texture, containing also a few scattered flints.

Dr. Rowe has more recently measured this zone, and estimates its thickness at 170 feet.* Mr. Hill's measurements are given in the following section, and others must decide which estimate is most correct, but it may be mentioned that the height of the cliff at Holywell is given as 249 feet, and as there is Lower Chalk at the base the total thickness of the Middle Chalk can hardly be 270 feet, as Dr. Rowe makes it.

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* Proc. Geol. Assoc., Vol. xvi. p. 322 (1900).

Places where the lower part of the Melbourn Rock can be examined have been mentioned under the head of Lower Chalk (see p. 75). The following is a detailed description of the beds as measured in and below the Holywell Quarries from the base of the chalk with regular layers of flints* :—

			ft.	in.
Zone of *Ter. gracilis.*		White chalk, weathering somewhat rough and lumpy, with scattered flints - - about	15	0
		Soft creamy white chalk, with occasional thin seams of marl ; no flints - - - - -	118	0
Zone of *Rhynchonella Cuvieri.* 82½ feet.		Firm massive chalk in regular courses - -	27	0
		Firm chalk with hard creamy nodules - - -	1	0
		Firm whitish chalk in massive courses - -	10	0
		Layer of yellowish grey marly chalk - - -	0	8
		Creamy white chalk with a few nodules -	6	0
		Hard creamy yellow chalk - - - - -	9	0
		Hard creamy-yellow chalk, courses of smooth chalk alternating with beds full of hard nodules	6	0
	Melbourn Rock, 23 feet.	Very hard creamy chalk in two massive beds	5	0
		Very hard yellowish shelly chalk, with layers of hard cream-coloured nodules - - -	7	0
		Course of smoother chalk, separated from the adjoining beds by thin seams of marl - -	2	4
		Two courses of hard nodular whitish chalk, streaked with greenish-grey veins, and divided by a seam of marl - - - -	3	3
		Course of smooth chalk - - - -	0	9
		Two courses of hard nodular whitish chalk streaked with greenish grey and divided by a seam of marl - - - -	3	3
		Course of hard greyish-white chalk - -	1	6
Zone of *Act. plenus.*—Grey marls (see p. 75).				
			215	6

Passing the local anticline south-west of Holywell, where the Gault and Greensand rise into the base of the cliff, and rounding the point of Beachy Head, we come to where the westerly dip finally brings the Middle Chalk down to the beach. (See Fig 27.)

Here in 1897 the Melbourn Rock was covered by a large landslip, but above this there is a complete section up into the Upper Chalk. Several layers of yellowish nodules can be seen in the zone of *Rhynchonella Cuvieri,* and the shelly chalk of this zone appears to pass more gradually into the soft white chalk here than at Holywell. The massive beds of the *Terebratulina* zone are generally separated by a thin layer of veiny chalk, which sometimes passes into a thin seam of greyish marl, and in the upper part there are several layers or bands of marl from 6 to 9 inches thick. This chalk with marly veins has a thickness of 95 feet.

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*Mr W. R. Andrews informs us that the chalk with flints seen in 1897 has since been cut away for the erection of a pumping station in connection with the waterworks.

Above this, as at Dover, the chalk has no longer a smooth fracture, but has a lumpy texture, and is without any well-defined planes of bedding, the few flints that occur being scattered and not arranged in lines. *Holaster planus* occurs in this chalk, but Micrasters are rare, and we regard it as the highest part of the *Terebratulina* zone. There is quite 20 feet of this lumpy chalk at Beachy Head before reaching a band of still more rough and nodular chalk, in which Micrasters are common, and it is the latter that we take as the base of the *Holaster planus* zone, and consequently refer to the Upper Chalk.

The following measurements of the beds exposed below Beachy Head were taken by Mr. Hill in 1897 :—

		feet.
Upper Chalk —Zone of *Holaster planus*		
Terebratulina Zone, 126 feet.	Rough lumpy creamy-white chalk, passing down into firm white chalk ; a few scattered flints at the top - - - - - - - - - -	21
	Firm white chalk in massive courses, from 12 to 27 feet thick, divided by layers of soft marl from 6 to 9 inches thick. Some of the beds are mottled with grey - - - - - - - - - -	93
	Firm white chalk in thick beds, divided by thin seams of marl - - - - -	12
Zone of *Rhync. Cuvieri*, 88 feet.	Firm white chalk, with many fragments of Inoceramus shell ; in courses divided by thin seams of marl - - - - - - - - - - -	11
	Rather hard white chalk, streaked with greenish grey, in thick beds containing much Inoceramus shell. Layers of nodules can be seen in the cliff - - - - - - - - - - -	54
	Hard rough whitish chalk, veined with greenish-grey, in courses separated by thin seams of marl (Melbourn Rock) - - - - - seen for	10
	Lower beds concealed by landslip - - -	? 13
		214

2. Neighbourhood of Lewes.

The range of hills which runs from Newtimber through Ditchling Beacon to Lewes coincides with the axis of a synclinal flexure, parallel to which there is a corresponding anticline passing through Poynings, Pangdean, Falmer, Kingstone, and Beddingham.

The structure of the hill range is illustrated by the accompanying section, Fig. 71, which has been drawn from a sketch and data furnished by Mr. C. Reid. At Lewes the range is breached by the valley of the Ouse, and the section is drawn through the "Cliff Hills" on the eastern side of the Ouse Valley. It will be seen that the dips are considerable, about 25° on each side of the syncline, so that at Lewes not only the Middle Chalk but also some of the Upper is brought down to the level of the river.

The following particulars respecting the exposures of the Middle Chalk near Lewes are compiled partly from notes supplied by Mr. Reid and Mr. Rhodes, and partly from the researches of Professor Barrois already mentioned.

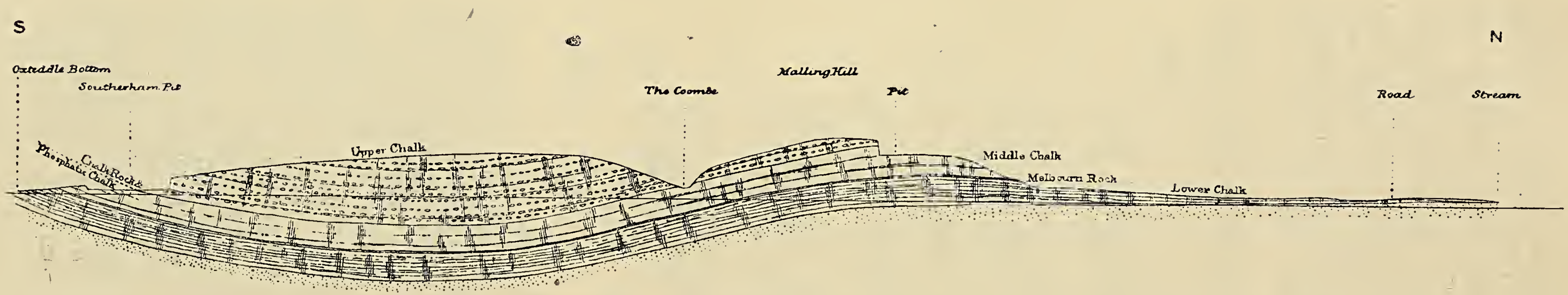

FIG. 71.—Section through the Cliff Hills east of Lewes. Horizontal and Vertical Scales, 6 inches to a mile.

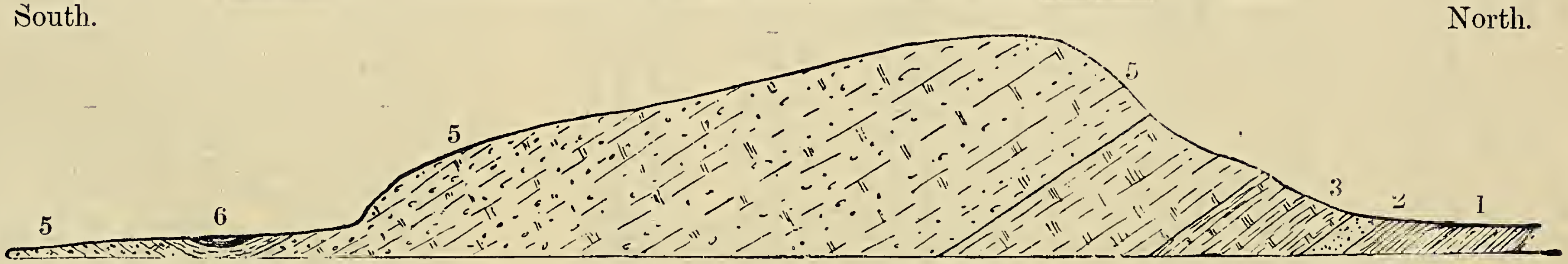

FIG. 72.—Diagram-section across the South Downs near Amberley and Arundel (by C. Reid), Horizontal Scale, one inch to a mile. Vertical Scale, about 500 feet to an inch.

6. Eocene Beds.	4. Middle Chalk.	2. Malmstone.
5. Upper Chalk.	3. Lower Chalk.	1. Gault.

Different parts of the Middle Chalk are exposed in the following quarries near Lewes :—

1. A quarry west of Glyndebourn, giving a clear section from the Melbourn Rock up into the *Terebratulina* zone.
2. An old quarry further west, which shows part of the *Terebratulina* zone.
3. Mount Caburn quarry ; a large quarry, which, with its entrance roadway, exposes nearly the whole of the Middle Chalk, the beds dipping north.
4. Southerham limekilns, where portions of three zones are exposed, but not a continuous section ; beds dipping north.
5. The new quarry at Malling, opened in the *Terebratulina* zone and that of *Holaster planus ;* beds dipping south.
6. Bridgewick pit, east of the last ; the lower part of this is obscured by talus, but the face above shows portions of the same two zones.
7. The first cutting on the railway north of Lewes, traversing parts of the zones of *Rhynchonella Cuvieri* and *Terebratulina.*

Of these exposures, the first, third, and fifth present the best sections of the lower zones, and of these we shall give some particulars, as well as of the fourth and fifth.

The section in Glyndebourn Pit, three furlongs west of Glyndebourn Farm, from notes supplied by Mr. Reid and Mr. Rhodes, is as follows :—

	feet.
5. White chalk without flints, inaccessible, but showing two thin layers of marl	30–40
4. Nodular chalk with some green-coated nodules	1
3. White chalk with grey streaks	20
2. Firm white chalk with a marked nodular bed at the top containing green-coated lumps	30
1. Hard rocky chalk—Melbourn Rock	? 10
About	90

From the Bed No. 2 Mr. Rhodes obtained the following fossils, which were named by Messrs. Sharman and Newton :—

Discoidea subuculus.
Galerites subrotundus
Terebratula semiglobosa.
Rhynchonella Cuvieri.
Inoceramus mytiloides
Inoceramus like Lamarcki.
Spondylus sp.
Ammonites [Hoplites] leptophyllus ?
„ [Acanth.] nodosoides.

From the overlying chalk (No. 3) he obtained *Terebratula semiglobosa*, *Terebratulina gracilis* var. *lata*, and *Inoceramus* sp.

Mount Caburn Quarry.—This was described in some detail by Dr. Barrois in 1876 ("Recherches," p. 28), and it was visited by Mr. Rhodes in 1896, by which time it would seem to have been enlarged and cut back further than when seen by Dr. Barrois.

The following account has been taken chiefly from the notes of Mr. Rhodes :—

	feet.
Chalk with frequent bands of flint nodules, inaccessible, but specimens of *Micraster cortestudinarium* and *Echinocorys vulgaris* found on the pit floor seem to have come from this	40
Chalk with several layers of yellow and green-coated nodules, and a hard yellowish bed at the base ; flints rare and scattered (zone of *Hol. planus*) - - - - - - -	12
Compact homogeneous white chalk, with several thin layers of grey marl ; no flints except quite at the top, where there is a single layer of small black flints. Fossils found principally about 20 feet from the top - - - - - - -	80
Hard chalk, with a marked nodular bed at the top (zone of *Rhynch. Cuvieri*) - - - - - - - - seen for	8
	140

Lower beds, including the Melbourn Rock, can be seen in the road-cutting which leads to the quarry. The beds dip at an angle of 10 to 12° to the north.

The Ranscombe Quarry, a little farther west, must have shown a similar section in 1875, as described by Prof. Barrois, who was fortunate in obtaining five species of *Ammonites* from it, but it is now disused and obscured by talus.

Southerham Limekiln Quarry, the position of which is indicated in Fig. 66, must once have shown a fine section through the whole of the Middle Chalk. It has been mentioned by Mantell and Martin, and in all probability the former obtained many fossils from it. The present workings, however, are chiefly at the northern end in the higher zones, and the southern part of the great excavation is much obscured and overgrown. The beds have a northerly dip of about 25°.

At the southern end, however, Mr. Rhodes found a small exposure of the Melbourn Rock, succeeded by rough shelly chalk with *Inoceramus mytiloides* and *Rhynchonella Cuvieri*. The top of this zone is marked by a bed of hard chalk about a foot thick, yellowish, and containing some yellow-coated nodules. Above this are small exposures in the *Terebratulina* zone.

The Malling quarries lie to the north-east of Lewes, at the north end of the section Fig. 71, and that called the " new pit " must formerly have shown an excellent vertical cut through the *Terebratulina* zone. Mr. Rhodes reports that the quarry is about 120 feet deep, but that the lower part is now much obscured by talus and grass ; the upper face shows the following beds :—

		feet.
	Rough chalk with scattered flints and two layers of flints near the top, below a seam of marl (this chalk is not accessible) - - - - - - - - - about	40
Terebratulina Zone.	Massive white chalk without flints (*Holaster planus*). - - - - - - - - about	10
	Seam of grey marl.	
	White chalk without flints, containing *Ter. gracilis* var. *lata*, *Galerites subrotundus*, and *Ammonites* [*Pachydiscus*] *peramplus* - seen for about	20

3. AMBERLEY, HOUGHTON, AND DUNCTON.

The only other district about which we have any special information is that which includes the villages of Amberley, Houghton, Bury, Bignor, Upper Waltham, and Duncton. The exposures in this district have been examined by Mr. C. Reid and Mr. W. Hill.

Zone of Rhynchonella Cuvieri.

Rough nodular chalk which cannot be far above the Melbourn Rock is exposed in the most northern part of the large quarry by Amberley Station, close to the main road. About 25 or 30 feet of this chalk is seen, and from it Mr. Hill obtained *Inoceramus mytiloides* and a few *Rhynchonella Cuvieri.*

The base of the Melbourn Rock is exposed in the quarry south of Bury, and Mr. Reid saw good sections of the lower half of the Middle Chalk in the road cuttings south of Bignor and near Coldharbour Farm. He could trace the outcrop of the Melbourn Rock continuously along the escarpment from Sutton to Duncton. A pit by the road, a little below the top of Duncton Hill, about 700 yards south-west of the church, exposes the zone of *Rhynchonella Cuvieri,* that fossil and *Inoceramus mytiloides* being abundant.

Mr. Reid's survey also showed that a westerly extension of the Greenhurst anticline causes the Middle Chalk to be exposed continuously from Farm Hill and Upper Waltham along the Lavant valley as far as West Dean. The Melbourn Rock is exposed at several points round the inlier of Lower Chalk at Littleham Farm.

Terebratulina Zone.

The best section of this zone in western Sussex is that of the large quarry by Amberley Station.

Writing of this quarry in 1850, Mr. Dixon said,* "the large quarry on the opposite side of the River Arun (to Houghton) is called Balcombe-pit, and is of the Lower Chalk formation, or that without flints." Among fossils found here he mentions *Radiolites,* "bones of Turtles and Fishes in very good preservation, particularly *Beryx ornatus* and *Macropoma Mantelli,* Echinoderms and Crustaceans, especially *Enoploclytia Leachi.* The nodules of sulphide of iron here often contain a *Terebratula* or other small shell in the centre, which elsewhere is rare."

Professor Barrois has also described this pit (Recherches, p. 33) giving the following particulars :—

	feet.
5. Compact chalk with scattered flints.	
4. Shaly chalk with scattered grey flints, *Terebratula semiglobosa, Inoceramus sp.* - - - - - - -	6½
3. Layer of yellowish nodules.	
2. Homogeneous white chalk, in courses separated by seams of grey marl - - - - - - - - -	82
1. Hard compact white chalk, in beds about 3 feet thick, separated by marly seams, which contain nodules (of chalk) - - - - - - - - - - - -	33
About	121

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*Geology of Sussex, Second Edition, 1878, p. 130.

Mr. Hill visited the quarry in 1897, and contributes the following note:—Here about 110 feet of Turonian Chalk is traversed; about a third of the main face is now obscured by talus, but smaller cuttings to the right and left expose the lower parts. The chalk is for the most part soft and white; flints occur near the top, and there is at least one layer of large, massive flints. *Terebratulina gracilis* var. *lata* is fairly common, *Spondylus spinosus and Sp. latus* also occurred, and in a fallen block containing some of the large flints a crushed Echinoderm, apparently *Holaster planus*, was found.

FOSSILS OF THE MIDDLE CHALK IN SUSSEX.

The following is a list of such fossils as can at present be referred with certainty to the Middle Chalk of Sussex, and to their proper zonal horizon. No doubt many of the fossils figured by Mantell and Dixon, especially many of the remains of Fishes and Reptiles, were obtained from this division of the Chalk, for, as Dr. Barrois has pointed out, the zones of *Rhynchonella Cuvieri* and of *Terebratulina* seem to be rich in such remains along the range of the South Downs. But in most cases the describers were content with saying that the specimens came from the Chalk Marl, Lower Chalk or Upper Chalk, as then understood, and even when the locality was also mentioned it is not often possible to ascertain from what zone the specimen may have come.

The reference of the numerous fossils which have been found in this county to their proper zone is a piece of work which may be commended to the local geologists, for it could not be undertaken in connection with this memoir.

The list now given is based on the following information—(1) The species recorded by Professor Barrois in his well-known "Recherches;" (2) lists of fossils found by Mr. Maddock in each zone during his residence at Eastbourne; (3) fossils collected for the Survey by Mr. Rhodes from localities near Lewes, and identified by Messrs. Sharman and Newton; (4) fossils found and recorded by Dr. Rowe in Proc. Geol. Assoc., Vol. xvi., p. 359 *et seq.* (1900); (5) those recorded by Mr. H. Willett in his "Catalogue of the Cretaceous Fossils in the Brighton Museum" (1871) as from the Middle Chalk of Malling and Houghton.

The localities are indicated as follows: e=Beachy Head, s=near Lewes, and a=Amberley and Houghton. Mr. Willett's fossils may have come from either zone and are entered in a third column.

—	Zone of Rhynch. Cuvieri.	Zone of Tereb. gracilis.	Zone Un known.
Reptila.			
Cimoliosaurus Bernardi, *Owen* (tooth)	–	–	s
Polyptychodon interruptus *Owen* (teeth)	–	–	s
Pisces.			
Beryx ornatus, *Ag.* (Hoplopteryx)	–	–	s a
,, radians, *Ag.* (Ctenothrissa)	a	e s	s
Belonostomus cinctus, *Ag.*	–	–	s
Cimolichthys lewesiensis, *Leidy*	–	–	s a
Corax falcatus, *Ag.*	–	e	
,, maximus	–	–	a
Dercetis elongatus, *Ag.*	–	–	s
Enchodus lewesiensis, *Mant.*	–	–	s a
Gyrodus cretaceus, *Ag.*	–	–	s
Homonotus dorsatus, *Ag.*	–	–	s
Lamna appendiculata, *Ag.*	e a	e s	
Lophiostomus Dixoni, *Ag.*	–	–	s
Macropoma Mantelli, *Ag.*	–	–	s
Microdon occipitalis, *Dixon*	–	–	s
Plethodus expansus, *Dixon*	–	–	s
Notidanus microdon, *Ag.*	e	e	
Oxyrhina crassidens, *Dixon*	e	e	
,, Mantelli, *Ag.*	–	a	
Ptychodus mammillaris, *Ag.*	e	e s	s
,, latissimus, *Ag.*	–	–	s
Scapanorhynchus subulatus, *Ag.*	–	e s	
Vertebræ and scales	e	e	
Cephalopoda.			
Ammonites [Hapl.] leptophyllus *Sharpe*	s	–	
,, [,,] lewesiensis, *Mant.*	s	–	s
,, [Acanth.] carolinus, *d'Orb.*	–	s	
,, [,,] nodosoides, *Schlüter*	s	–	
,, [Pachydiscus] peramplus, *Mant.*	–	s	
,, [Acanth.] rusticus, *Sow.*	–	–	s
,, [Prionotropis] Woolgari, *Mant.*	–	s	
Hamites angustus, *Sow.*	–	s	
Gasteropoda.			
Dentalium sp.	–	–	s
Pleurotomaria perspectiva, *Mant.*	–	–	s
Solariella gemmata, *Sow.*	–	–	s
Turritella sp.	–	–	s
Lamellibranchiata.			
Inoceramus Brongniarti, *Sow.*	–	e s a	s
,, Cuvieri, *Sow.*	e s	e s	s
,, mytiloides, *Sow.*	e s a	e	
Lima sp.	e	–	
Ostrea normaniana, *d'Orb.*	e	e s	
,, hippopodium, *d'Orb.*	–	e	
,, semiplana, *Sow.*	a	e s	
,, vesicularis, *Lam.*	–	e s	

———	Zone of Rhynch. Cuvieri.			Zone of Tereb. gracilis.			Zone Un-known.
Pecten Beaveri, *Sow.*		—		e			
,, (Neithea) 5-costatus, *Sow.*		—		e			s
Plicatula sigillina, *Woodw.*	e			e			a
Radiolites Mortoni, *Mant.*		—			—		s
Spondylus latus, *Sow.*		—		e		a	
,, dutempleanus, *d'Orb.*	e				—		
,, spinosus, *Sow.*		—		e	s	a	
Teredo amphisbæna, *Goldf.*		s			—		s
Brachiopoda.							
Rhynchonella Cuvieri, *d'Orb.*	e	s	a	e		a	
,, limbata, *Schloth.*		—		e			
,, plicatilis, *Sow.*		—		e	s		
,, reedensis, *Eth.*		—		e			
Terebratulina gracilis, var. lata, *Eth.*	e	s		e	s	a	
,, striata, *Wahl.*	e				s	a	
Terebratula semiglobosa, *Sow.*	e	s	a	e	s	a	
Crustacea.							
Enoploclytia Leachi, *Mant.*		—		e		a	
,, sussexiensis, *Mant.*		—		e			
Loricula pulchella, *Sow.*		—			—		s
Pollicipes lævis, *Sow*		—		e			
Annelida.							
Serpula annulata, *Sow.*		—		e			
,, ilium, *Sow.*		—		e			
,, plana, *Woodw.*	e			e			
,, plexus, *Sow.*		—		e	s		s
Echinodermata.							
Cardiaster pygmæus, *Forbes*	e			e			
Cidaris Bowerbanki, *Forbes*		—		e			
,, dissimilis, *Forbes*		—			—		s
,, hirudo, *Sorig.*	e			e			
,, serrifera, *Forbes*	e			e			
,, subvesiculosa ? *d'Orb.*		—			s		
Cyphosoma radiatum, *Sorig.*		—		e	s		
,, granulosum, *Goldf.*		—			—		s
Discoidea Dixoni, *Forbes*		—		e			
,, minima, *Ag.*	e	s		e	s		
Echinocorys scutatus, *Leske*		—		e			
Galerites subrotundus, *Mant.*	e			e	s	a	s
Glyphocyphus radiatus, *Hoening.*	e				—		
Holaster planus, *Mant.*		—		e	s	a	
,, placenta, *Ag.*		—		e			
Hemiaster minimus, *Ag.*	e			e			
Metopaster Mantelli, *Forbes*		—			—		s
Mitraster compactus, *Forbes*		—			—		s
Micraster corbovis, *Forbes*		—		e			
Pentacrinus sp.	e			e			s
Salenia granulosa, *Forbes*		—		e			

—	Zone of Rhynch. Cuvieri.	Zone of Tereb. gracilis.	Zone Unknown.
Actinozoa.			
Parasmilia centralis, *Mant.*	—	s	s
Spongida.			
Cephalites catenifer, *Smith*	—	—	s
,, longitudinalis, *Smith*	—	—	s
,, paradoxus, *Smith*	—	—	s
Cliona cretacea, *Portl.*	—	e	
Craticularia Fittoni, *Mant.*	e	e	
Guettardia stellata, *Mich.*	e	e	s
Heterostinia obliqua, *Benett*	—	e	
Plocoscyphia convoluta, *Smith*	e	e	
,, labrosa, *Smith*	e	e	
Porosphæra globularis, *Phil.*	e	e	
Ventriculites decurrens, *Smith*	—	e	s
,, impressus, *Smith*	—	e	s
,, mammillaris, *Smith*	—	e	
,, radiatus, *Mant.*	—	e	

CHAPTER XXXI.

THE MIDDLE CHALK IN THE ISLE OF WIGHT.

General Description.

Starting from the southern side of Culver Point the outcrop of the Middle Chalk forms a narrow band along the Downs as far as Carisbrook Castle in consequence of the high dip. West of this the space occupied by this division widens out and extends southward owing to the flattening out of the beds between the two anticlinal folds described by Mr. Strahan as the Sandown and Brixton anticlines.* Neither of these flexures stretches completely across the island, and where one meets the other the beds flatten out and appear even to be deflexed into a short and shallow syncline which crosses the valley of the Medina between Rookley and Gatcombe Down (see Fig. 73).

North-west of Shorwell the dips become greater again as the influence of the Brixton anticline makes itself felt, and the basset surface of the Middle Chalk is again reduced to a narrow band, which runs into the sea at Compton Bay.

The first adequate description of the beds which form the Middle Chalk or Turonian of the Isle of Wight was that published by Professor Barrois in 1875.† In this memoir he clearly distinguished the zones of *Inoceramus labiatus* (=zone of *Rhynchonella Cuvieri*), of *Terebratulina gracilis* and of *Holaster planus*, and though in 1876 (Recherches, p. 107) he altered his opinion with regard to the last zone, we believe his original identifications to be correct.

In 1865 Mr. Whitaker gave some account of the Isle of Wight Chalk, and indicated a thin bed of hard chalk with a layer of green-coated nodules which he regarded as the equivalent of the Chalk Rock of Berkshire and Wiltshire, which he had described a few years earlier. As the bed is certainly not far from the horizon of the Chalk Rock, and as in those days zones and zonal fossils were little studied, it was a very probable correlation, and it has been accepted by all subsequent writers on the Isle of Wight. We know now that the true Chalk Rock lies in the zone where *Holaster planus* is associated with many Micrasters, and, as Professor Barrois pointed out in 1875, the fauna of this zone does not begin to come in till we get some feet higher than the layer of green-coated nodules, and above a seam of black marly clay. He then placed the nodule-bed in the *Terebratulina* zone, but, afterwards, assuming that this bed was

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* Geology of the Isle of Wight, Mem. Geol. Survey, Second Edition, p. 240, 1889.

† Bibliothèque de l'Ecole des Hautes Etudes, Sc. Nat., Tom. xiii.

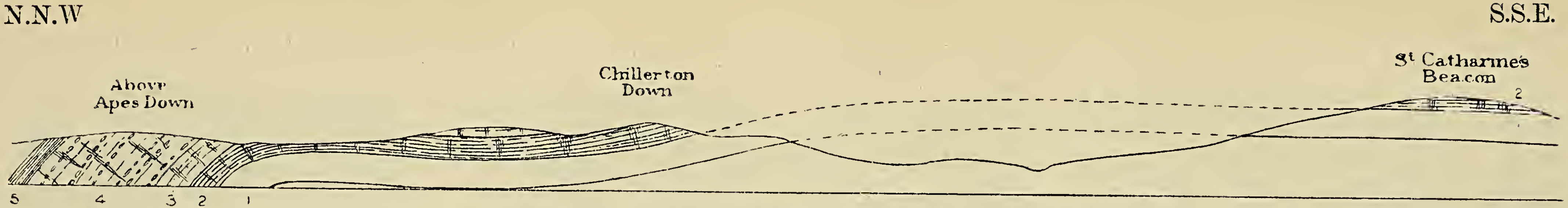

FIG. 73.—Section across the centre of the Isle of Wight.
Hor. Scale—one mile to one inch. Vertical Scale—1,600 feet to one inch.
5. Eocene. 4. Upper Chalk. 3. Middle Chalk. 2. Lower Chalk. 1. Selbornian.

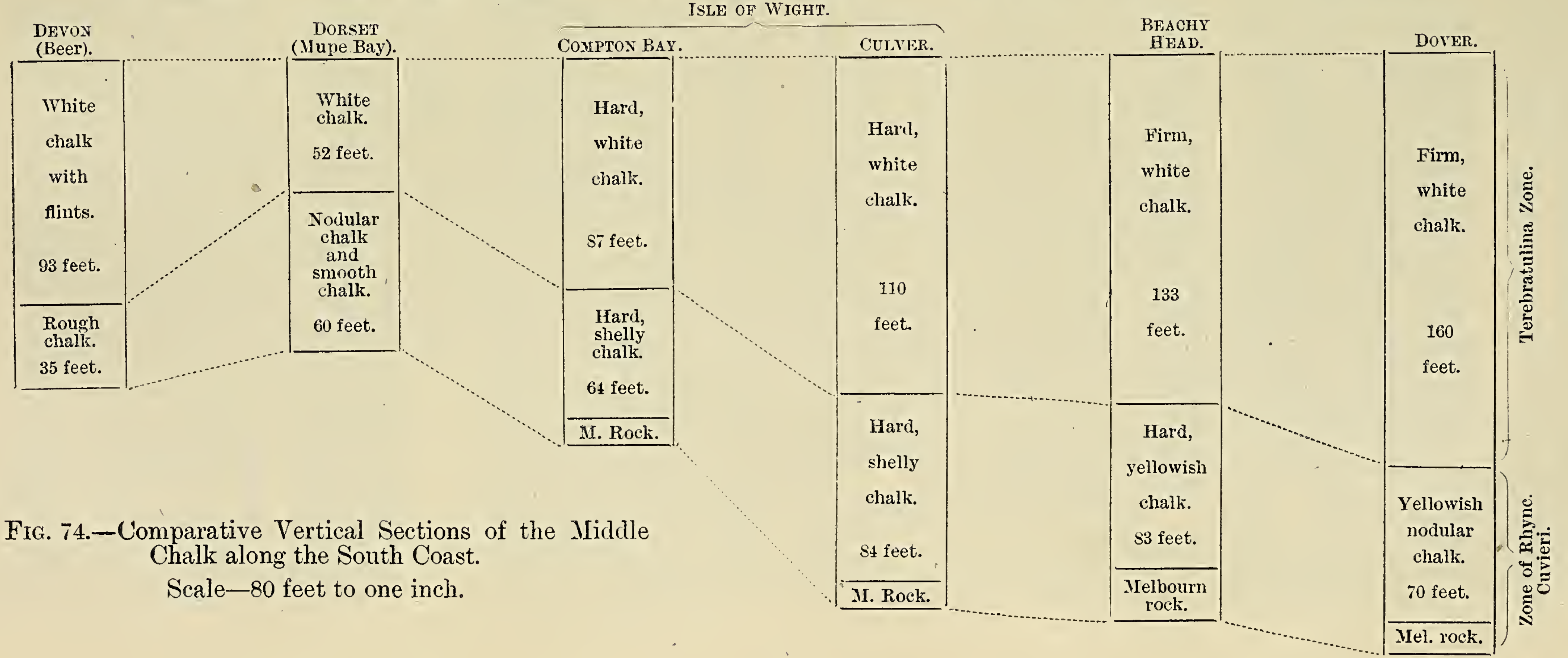
ISLE OF WIGHT.
DEVON (Beer).
White chalk with flints. 93 feet.
Rough chalk. 35 feet.
DORSET (Mupe Bay).
White chalk. 52 feet.
Nodular chalk and smooth chalk. 60 feet.
COMPTON BAY.
Hard, white chalk. 87 feet.
Hard, shelly chalk. 64 feet.
M. Rock.
CULVER.
Hard, white chalk. 110 feet.
Hard, shelly chalk. 84 feet.
M. Rock.
BEACHY HEAD.
Firm, white chalk. 133 feet.
Hard, yellowish chalk. 83 feet.
Melbourn rock.
DOVER.
Firm, white chalk. 160 feet.
Yellowish nodular chalk. 70 feet.
Mel. rock.
Terebratulina Zone.
Zone of Rhync. Cuvieri.

FIG. 74.—Comparative Vertical Sections of the Middle Chalk along the South Coast.
Scale—80 feet to one inch.

the equivalent of the Chalk-rock, he referred it to the zone of *Hol. planus*, and the overlying nodular chalk to the zone of *Micraster cortestudinarium*.

We think that Professor Barrois's first view was correct, and that the real mistake lay in the correlation of the layer of green nodules with the Chalk Rock. There is no doubt that beds resembling Chalk Rock occur at several horizons, and in the north of Hampshire there is one in the *Terebratulina* zone below true "Chalk Rock." The mere lithological resemblance carries little weight unless it is confirmed by the evidence of the fossils, and this is not the case in the Isle of Wight.

The characteristic fossils, *Holaster planus* and *Micraster Leskei* do not indeed become abundant till we get above another seam of marl which lies 8 or 9 feet higher than the seam of black marl or clay, and it is at this light grey marl that we propose to terminate the *Terebratulina* zone and with it the Middle Chalk.

We consider that the Chalk Rock of Wiltshire, Berkshire, and more northern counties is represented in the Isle of Wight by the lower part of the rough nodular chalk which overlies the upper seam of marl. These beds will be described in another volume under the head of Upper Chalk, and it is only necessary to note here that below them Micrasters are so rare that it is uncertain whether any specimen or fragment of one has yet been found in what we regard as Middle Chalk.

In passing from the eastern to the western extremity of the Isle of Wight the Middle Chalk undergoes a certain diminution of thickness. Mr. Strahan's measurements at Culver in 1887* gave a thickness of 183 feet 5 inches for the beds between the base of the Melbourn rock and the black clay-band above mentioned. In 1897 Mr. Hill succeeded in measuring the same beds in Compton Bay, and found the thickness only 141 feet 7 inches, showing a difference of about 42 feet (see Fig. 74). If we take the measurements up to the seam of grey marl they become 194 and 150 feet respectively.

STRATIGRAPHICAL DETAILS.

Complete sections of the Middle Chalk are exposed in the cliffs near Culver Point and in Compton Bay, and portions of this division are to be seen in some of the inland quarries. We shall take the exposures in order from east to west.

The greater part of the Culver Cliff section is difficult of access, but the highest and lowest beds can be easily reached, and Mr. Strahan was able to estimate the total thickness by measuring from point to point. The following account is based on that published by him in the Memoir on the Isle of Wight (1889), supplemented by notes taken by Mr. Hill on a more recent visit in 1897:—

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*See Geology of the Isle of Wight, Mem. Geol. Survey, Second Edition (1889) p. 89.

		ft.	in
Upper Chalk.—Rough nodular chalk.			
Terebratulina Zone, about 110 feet.	Seam of light grey marl	0	1
	Hard rough nodular chalk	10	0
	Layer of black clay	0	6
	Hard rough nodular chalk	8	0
	Hard greyish chalk, with a layer of hard green-coated nodules at the top	1	2
	Hard white chalk, rough at the top, but mostly in massive beds, separated by thin layers of marl; no flints - about	90	0
Zone of *Rhynch. Cuvieri*, 84 feet.	Hard whitish chalk in thinner beds, with many fragments and shells of *Inoceramus mytiloides*; *Rhynchonella Cuvieri* is less common	74	0
	Shaly chalk	2	0
	Hard bedded chalk, with layers of yellow-coated nodules and seams of greenish marl (Melbourn Rock)	8	3
Lower Chalk—Bluish marl (see p. 88).			
		194	0

The Melbourn Rock is well exposed in Mr. Mumm's quarry west of Yarbridge. The general section of this has been given on p. 88, and the details of the upper part are as follow:—

		ft.	in.
Hard white bedded chalk, with *Inoceramus mytiloides* and *Rhynch. Cuvieri* - more than		20	0
Melbourn Rock.	Hard white rough nodular chalk in regular beds, separated by marly partings	5	0
	Rough white nodular chalk in one bed	1	6
	Thin seam of greenish laminated marl	0	2
	Hard rough nodular whitish chalk, veined and streaked with greenish-grey	4	6
Lower Chalk—for details see p. 88		190	0

The highest part of the *Terebratulina* zone is exposed in a quarry half-a-mile west of Yarbridge. The beds seen are:—

		ft.	in.
Upper Chalk—Rough nodular chalk		14	0
Middle Chalk.	Seam of white marl	0	1
	Rough nodular chalk	8	0
	Seam of black clay	0	1
	Rough chalk, passing into smoother	8	0
	Layer of green-coated nodules	0	1
	Rough nodular chalk	2	6
	Smooth chalk	5	6

The Melbourn Rock was observed by Mr. Strahan in a pit on Mersley Down, north-west of Mersley Lodge, where it is about 9 feet thick, and is succeeded by 60 feet of hard chalk with marly partings, belonging to the zone of *Rhynch. Cuvieri*.

A large pit on Arreton Down to the westward exposes the top of the *Terebratulina* zone (18–20 feet) overlain by the nodular chalk of the *Hol. planus* zone, the succession being like that at Yarbridge, but not reaching the chalk with flints when seen in 1887.

A still better section of the two higher zones is to be seen in a quarry near the Convent, east of Carisbrook Castle, where the beds are dipping steeply to the north. This has been enlarged since 1887, and the top of the zone of *Rhynch. Cuvieri* appears to be shown; combining the notes taken by Mr. Strahan and Mr. Hill, the section is as follows, the limits of the three zones being indicated by the brackets:—

		ft.	in.
Zone of *H. planus.*	Nodular chalk with grey flints	? 10	0
	Nodular chalk without flints	5	0
Terebratulina Zone.	Thin seam of grey marl.		
	Smooth white chalk	7	6
	Dark marly clay	0	1
	Hard chalk	6	0
	Layer of green-coated nodules	0	3
	Nodular chalk	2	4
	Smooth chalk	4	0
	Fault Plane.		
	Smooth chalk in thick beds, with partings of marl at intervals of 2 to 4 feet; *Ter. gracilis* var. *lata*, about	75	0
Zone of *R. Cuvieri.*	Hard white chalk in thicker beds, with *Rh. Cuvieri* and *Inoc. mytiloides*—seen for	15	0
	About	125	0

Mr. Strahan remarks that "the fault mentioned above runs W. 15° S., very nearly along the strike of the strata which it throws down to the north, its effect being to depress out of sight an unknown thickness of the upper beds of the Middle Chalk. The dip points a little way west of north at 42°."

The lower part of the *Rh. Cuvieri* zone with the Melbourn Rock, about 40 feet in all, resting on the Belemnite marl, is exposed in an old pit now occupied by farm buildings about half a mile east of the above. This is the pit mentioned by Professor Barrois in 1875, from which he obtained *Inoceramus mytiloides*, *Rhynchonella Cuvieri*, and *Cidaris hirudo.*

Southwards by the Garstons and Gatcombe Down there are no good sections, but the base of the Middle Chalk caps the bold escarpment of Chillerton Down, and Mr. Strahan states that the Melbourn Rock is exposed at the top of the large quarry at Shorwell, but in 1887 it was inaccessible. Professor Barrois records fossils from Shorwell (*Ino. labiatus* zone) in his list, so that he must have found some accessible exposure there.

No other good sections present themselves till we reach the west end of Brixton Down, where the upper part of the zone, with much of the overlying nodular chalk, is well exposed in the highest quarry on the north side of the Calbourne and Brixton road. The section here was first described by Mr. Whitaker in 1865,* next by Professor Barrois in 1875,† and lastly by Mr. Strahan in the Survey Memoir (1889.) The line of black clay which usually occurs from 6 to 8 feet above the green-coated nodules was seen by both the earlier observers, but was not visible in 1887, owing probably to some local squeezing or faulting in the face then exposed. In 1897, however, Mr. Hill found it again shown in the proper position, and took the following measurements :—

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* Quart. Journ. Geol. Soc., Vol. xxi. p. 402.

† Description Géol. de la Craie de l'Ile de Wight, p. 18.

		ft.	in.
	Hard smooth white chalk with flints	15 or 20	
Terebratulina Zone.	Hard rough nodular chalk without flints; crushed Echinoderms are visible	21	0
	Seam of dark grey marly clay	0	2
	Hard rough nodular chalk	7	6
	Layer of green-coated nodules	0	6
	Rough knotty chalk, passing down into smooth white chalk	3 or 4	
	Smooth hard white chalk in thick beds, over	40	0

He did not note the presence of the second layer of marl, having no idea at that time that it was of any special importance; most probably it will be found to occur 7 or 8 feet above the layer of dark marly clay.

The most complete and accessible section of Middle Chalk is that in Compton Bay, and this was carefully measured by Mr. Hill in 1897, with the following results :—

		ft.	in.
	Very hard rough knotty chalk with flints; *Holaster planus*, *Micraster Leskei*		
Terebratulina Zone, about 87 feet.	Rough nodular chalk, with occasional *H. planus*	8	0
	Seam of dark grey marl	0	2
	Hard rough knotty chalk, without flints	1	0
	A layer of hard yellowish nodules at the top of very hard rough knotty chalk	1	3
	Very hard rough lumpy chalk, *Hol. planus*	3	6
	Layer of irregular green-coated brownish lumps	0	8
	Rather hard rough chalk, gradually passing down into smooth white chalk	6	0
	Hard smooth white chalk in massive courses, divided by seams of marl	40	0
	Hard white chalk in thinner courses, veined and streaked with greenish-grey	25	0
Zone of *Rh. Cuvieri*, 64 feet.	Hard white chalk in massive courses, with many fragments of *Inoc. mytiloides*	27	0
	Layer of yellow-coated nodules creamy-yellow inside, a conspicuous bed	1	0
	Hard white chalk with many fragments of *Inoc. mytiloides*, also *Rhynchonella Cuvieri*, *Cardiaster pygmæus*, and *Salenia granulosa* ?	26	0
	Hard rough nodular chalk in thin courses, separated by seams of greyish marl	6	0
	Very rough hard nodular chalk, in three courses separated by seams of marl	4	0
	Lower Chalk (see p. 89).		
	About	150	0

FOSSILS FROM THE MIDDLE CHALK OF THE ISLE OF WIGHT.

This list has been drawn up from the following sources :—(1) Lists kindly sent to us by Mr. Ch. Griffith, of Winchester, compiled from specimens collected by himself and Mr. R. M. Brydone. (2) Collections made for the Survey by Mr. Rhodes. (3) Lists published by Professor Barrois in his " Description de la Craie de l'Ile de Wight." (4) Fossils found by Mr. W. Hill at the places examined by him. These sources are distinguished in the list by the letters G, S, B, and H respectively.

———	Zone of R. Cuvieri.	Terebratulina Zone.
Ammonites [Pachydiscus] peramplus, *Mant.*	B	
,, [Prionotropis] Woolgari ? *Mant.*	B	
Aporrhais Mantelli ? *Gard.*	B	
Hippurites sp.	G	
Inoceramus Cuvieri, *Sow.*	G	B
,, Brongniarti, *Sow.*		B
,, Lamarcki, *Park.*	G	
,, mytiloides, *Sow.*	G S B H	
Ostrea canaliculata, *Sow.*	G	
,, hippopodium, *Nilss.*	B	B
,, normaniana, *d'Orb.*	G	G
,, semiplana, *Sow.*		B
,, vesicularis, *Lam.*	G	G
Plicatula sigillina, *Woodw.*	G	G
,, Barroisi, *Peron*	H	
Spondylus dutempleanus, *d'Orb.*		G
,, latus, *Sow.*		
,, spinosus, *Sow.*		G B
Rhynchonella Cuvieri, *d'Orb.*	G S B H	G B
,, mantelliana, *Sow.*	S	
,, plicatilis, *Sow.*	S	G
,, reedensis, *Eth.*		G
Terebratula carnea, *Sow.*		G
,, semiglobosa, *Sow.*	G S B H	G B
Terebratulina gracilis, var. *lata*, *Eth.*		G B
,, triata, *Wahl.*	H	G B
Defranci sp.		G
Serpula ampullacea, *Sow.*		G
Bourgueticrinus sp.		G
Cardiaster pygmæus, *Forbes*	H	
Cidaris clavigera ? *Koenig.* (=C. Sorigneti)		G
,, hirudo, *Sorig.*	G B	
Cyphosoma radiatum, *Sorig.*		G
,, sp.		G
Discoidea minima, *Ag.*	B H	
,, subuculus ? *Klein*	G H	
Echinocyphus difficilis *Ag*		G
Galerites subrotundus, *Mant.*		G
Holaster planus, *Mant.*		G
Mitraster rugatus, *Forbes*		G
Pentacrinus Agassizi, *Hag.*		G
Salenia granulosa, *Forbes*	H	
Porosphæra globularis, *Phil.*		G

CHAPTER XXXII.

THE MIDDLE CHALK IN SOUTH DORSET.

General Description.

The Middle Chalk of South Dorset resembles that of the Isle of Wight, but its thickness appears to be rather less where the most satisfactory measurements can be made, being only about 128 feet in Ballard cliff and about 134 at White Nothe.

A peculiarity in the Middle Chalk of Dorset is the setting in of a band of hard smooth chalk at the base. This band is six feet thick in Ballard cliff and thickens westward till it is more than 20 feet in Mupe Bay and Lulworth Cove ; west of that we have no measurement of its thickness, but it probably becomes less. As in other parts of England the Belemnite Marls are succeeded directly by the Melbourn Rock, we have had some doubt whether this intermediate band should be regarded as belonging to the Lower or to the Middle Chalk. It contains very few fossils, but such as do occur appear to be of Middle Chalk species; further, in some localities there is no very clear demarcation between it and the representative of the Melbourn Rock. Consequently we have grouped these beds as Middle Chalk and Dr. Rowe informs us that he takes the same view.

The first description of the zones composing the Middle Chalk in the coast sections was that given by Professor Barrois in 1876 ("Recherches" pp. 78 to 102). The district was re-surveyed by Mr. Strahan in 1888–90, and is described in his memoir on the "Geology of the Isle of Purbeck and Weymouth" (1898). In this he recognises the Melbourn Rock at the base of the stage, and for its upper limit he takes a layer of green coated nodules, which he regards as the equivalent of the Chalk Rock and places at the base of the Upper Chalk. This layer is no doubt the equivalent of the layer which has been called Chalk Rock in the Isle of Wight, and which we have discussed in the last chapter.

We feel sure, however, that the true base of the Upper Chalk is to be found rather higher up, and that it must be taken, as in the Isle of Wight, where Micrasters become abundant and are associated with *Echinocorys scutatus* as well as *Holaster planus*. Fortunately these coast sections have been studied during the presen summer (1899) by Dr. A. W. Rowe and Mr. C. D. Sherborn, and their careful collection of the fossils and knowledge of the zonal faunas has put the matter beyond doubt. They permit me to say that, so far as the Mupe Bay section is concerned, the base of the zone of *H. planus* should, in their opinion, be taken at the layer of flints which there occurs 15 feet above the double layer of green-coated nodules.

Since the above was written, Dr. Rowe's description of the Dorset coast sections has been published,* and I have availed myself of the information it contains.

Stratigraphical Details.

A complete section of the Middle Chalk is furnished by Ballard cliff, north of Swanage. Combining the accounts of this given by Professor Barrois in 1876 and by Mr. Strahan in 1898 the succession appears to be as follows:—

		feet
Upper Chalk, with many flints (see Volume III.).		
Terebratulina Zone	Chalk without flints, massive but somewhat lumpy, with a layer of hard green-coated nodules at the base	about 20
	Hard rough and lumpy chalk	,, 6
	Smooth thick-bedded chalk, with partings of marl	,, 60
Zone of *Rh. Cuvieri.*	Rough chalk, becoming nodular below	,, 30
	Rough, nodular and flaky chalk, with sparry joints (Melbourn Rock)	6
	Smooth compact chalk in thin beds with marly partings	6
		128

The Melbourn Rock still forms a well-marked band near the base and from the chalk which overlies it Mr. Rhodes obtained the usual fossils of the *Rhynchonella Cuvieri* zone, the only species of special interest being *Ammonites Cunningtoni.* The section is often partially obscured by falls and slips, so that it is difficult to measure it or to collect from it in detail. Mr. Rhodes found *Terebratulina gracilis* var. *lata* fairly abundant in the upper 20 feet of chalk below the green-coated nodules, while *Holaster planus* was common above that layer and in a band of rough chalk with sponge remains. At the top of the rough nodular chalk he found *Micraster corbovis, Ter. gracilis* var. *lata* and *Porosphæra globularis*†, and he did not find any Micrasters below this horizon.

Of this locality Dr. Rowe writes:—"We landed near Ballard Point on the *T. gracilis* beds and found a wonderfully air-weathered section. The double band of yellow-green nodules . . . is here well developed and is, as in all other sections on this coast. well down in the *T. gracilis* zone. This cliff-face was studded with fossils and it is the only exposure in this zone which yielded a good list. We obtained on this small face thirty-five species." Among those mentioned are *Cidaris serrifera, Pentacrinus Agassizi, Hemiaster minimus, Holaster planus, Inoceramus Cuvieri, Turbo gemmatus* and the Bryozoa *Homæosolen ramulosum* and *Diastopora oceani.*

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* Proc. Geol. Assoc. Vol. xvii., p. 1 (1901).

† In the Memoir on the Isle of Purbeck (p. 171) these fossils were by mistake included in the list of those from the beds below the green nodules.

Mr. Strahan mentions several exposures of the Melbourn Rock and a pit near Woolgarston which exposes the uppermost nodular chalk including the layer of green-coated nodules, and from this layer Mr. Rhodes obtained a number of fossils. He remarks also that " A good section [of the Middle Chalk] is afforded in the railway cutting at Corfe Castle, though the freshly exposed surface does not exhibit the characteristic aspect of the various rock-bands so clearly as the old quarries; the Chalk Rock* crops out on the east side of the cutting 74 yards north from the centre of the bridge at the Manse." At this place the total thickness of nodular chalk from the layer of green nodules to the base of the Upper chalk appears to be only 15½ feet.

At Knowle, in some quarries north-east of the church, Mr. Strahan saw "massive chalk in bands of 1 to 3 feet in thickness, with occasional small grey cylindrical flints and with nodular bands, resting upon about 30 feet of nodular chalk." The latter doubtless belongs to the zone of *Rhynchonella Cuvieri* and the higher beds to the *Terebratulina* zone. In the marl pits at Knowle Hill still lower beds were seen, the section being as follows:—

		feet.
Zone of *Rh. Cuvieri.*	Hard nodular chalk - - -	20
	Shaly nodular chalk - - - -	6
Belemnite Marl.	Chalk and marl interbedded - - - -	3
	Marl - - - - - - - -	12

The cliff section of the Middle Chalk in Warborrow Bay is described by Mr. Strahan as not easily accessible, but the beds are on the whole more nodular than those at Ballard cliff. The layer of green-coated nodules can be reached, and there is 15 feet of nodular chalk above it, while below his measurements gave a thickness of 113 feet to the base of the nodular chalk in the zone of *Rhync. Cuvieri*, but below this there is about 20 feet of chalk which is not nodular, consisting of smooth homogeneous chalk in regular beds with partings of greenish marl. Here, therefore, the total thickness of Middle Chalk seems to be 148 feet; but Dr. Rowe found it impossible to measure the section in 1900.

In Mupe Bay the beds are more accessible, but as they dip northward at increasing angles till they are actually vertical, very small portions of them can be reached and few fossils can be obtained. Mr. Strahan's account gives a thickness of 97 feet from the top of the Belemnite marl to the lower of two layers of green-coated nodules. Above this are about 17 feet of nodular chalk, which must be included in the *Terebratulina* zone, and these thicknesses make a total of 114 feet.

Mr. W. Hill took some measurements here in 1897 which confirm those of Mr. Strahan and make the succession as follows:—

	feet.
A layer of flints (base of Upper Chalk).	
Rough nodular chalk without flints - - - - - -	15

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*By this term Mr. Strahan means the layer of green nodules and about 2 feet of nodular chalk beneath it.

	feet.
Two layers of green-coated nodules, with hard rough nodular chalk between	1½
Hard nodular white chalk, with layers of white nodules in a darker matrix	10
White chalk, hard, but rather less nodular	25
Nodular white chalk with *Inoceramus mytiloides*, much smoothed by the wash of the sea, but having a bed of very nodular chalk at the base about	38
Hard white chalk with greenish marly partings and a nodular bed rather above the middle	22
About	111

Professor Barrois records *Echinocorys gibbus* (a variety of *E. scutatus*) from the nodular chalk below the flint layer, but neither Mr. Rhodes nor Dr. Rowe found any *Echinocorys* in this band. If the specimen found by Professor Barrois was really *Echinocorys* and not *Holaster* it must be a very rare fossil at this horizon.

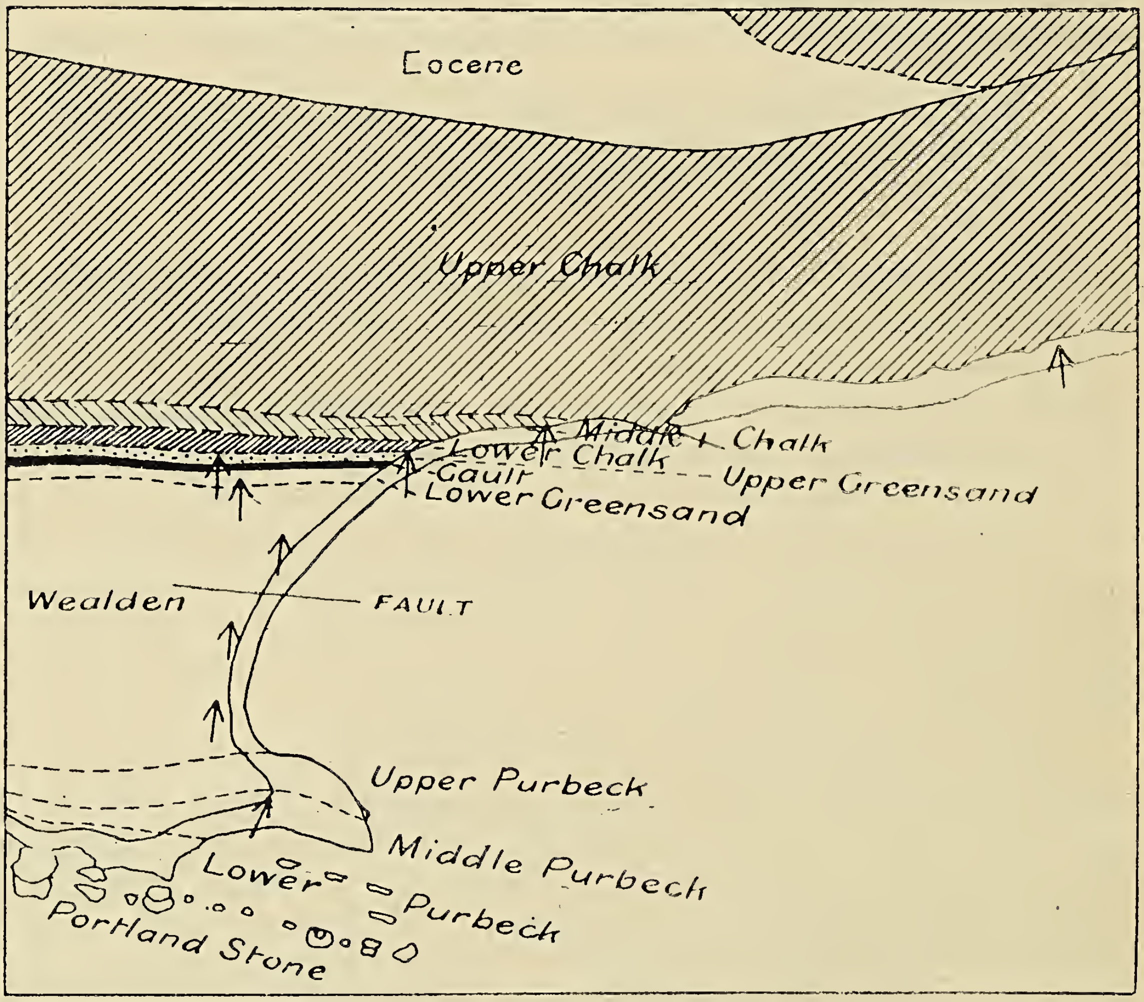
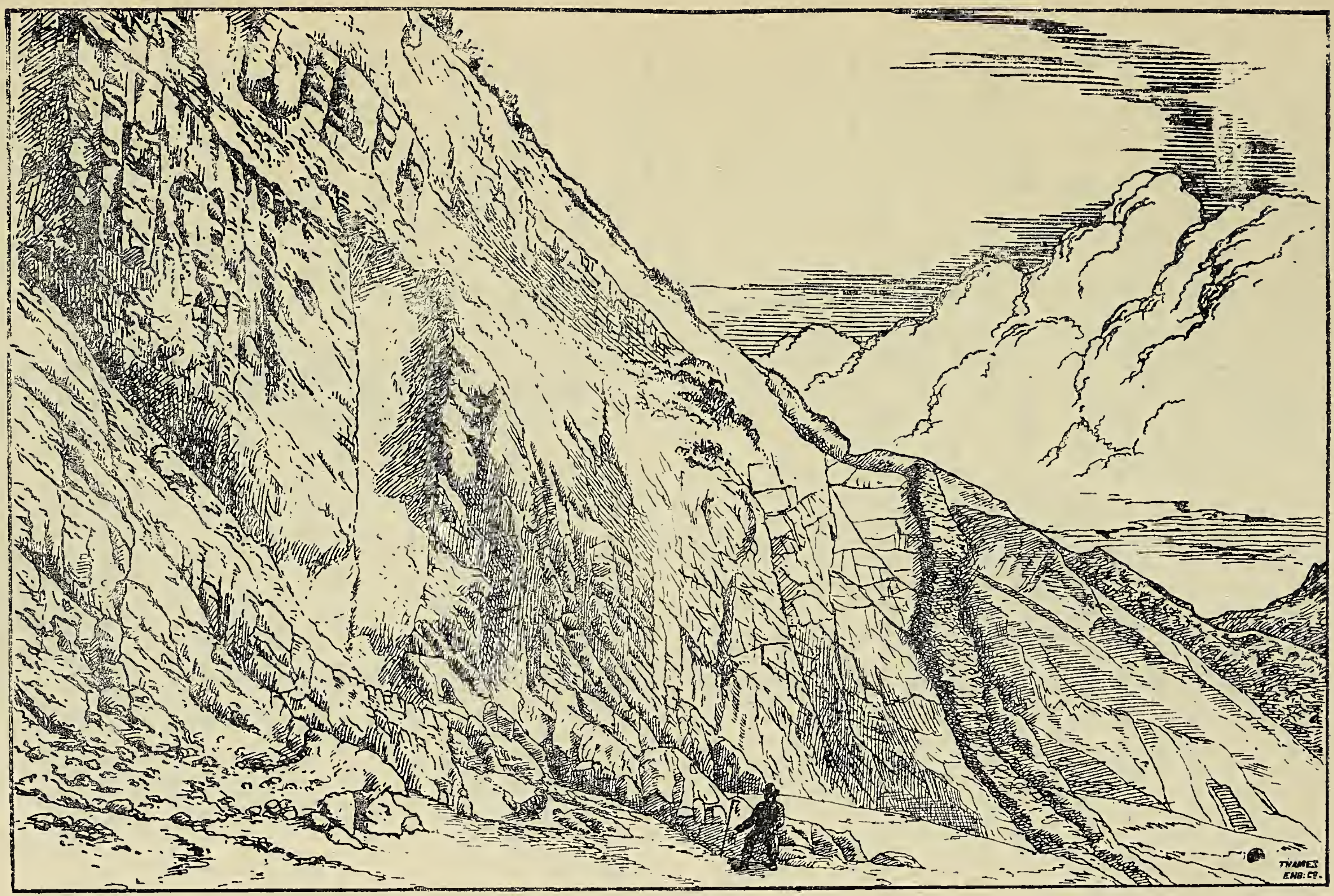


Fig. 75.—Sketch-map of Mupe Bay.

Scale, six inches to a mile.

In Lulworth Cove the upper part of the Middle Chalk is not now accessible, although Professor Barrois seems to have reached nearly the whole of it in 1875. The following notes were taken by Mr. Hill in 1893: The *Terebratulina* zone consists of somewhat rough chalk in thick beds; this passes down into


Thrust Plane.
Thrust Plane.
Middle Chalk.
Lower Chalk.
Chlor. Marl.
Upper Greensand.
THAMES ENG: Co.

The band between two vertical lines at the top of the Lower Chalk represents the Belemnite Marl; it is cut off at top and bottom by the thrust-planes.

Fig. 76.—Part of the East side of Durdle Cove, showing Middle and Lower Chalk in vertical position.

rough nodular chalk, breaking with an uneven fracture, of which between 30 and 40 feet could be reached, and the latter rests on about 25 feet of harder and more nodular chalk. At the bottom of this chalk *Inoceramus mytiloides, Rhynchonella Cuvieri* and *Discoidea minima* were not uncommon, but the *Inoceramus* was most abundant from 20 to 30 feet up. Between this nodular chalk and the Belemnite Marl is about 20 feet of hard white chalk with greenish veins. It was not easy to take any plane as a line of division between the two zones.

Professor Barrois estimated the thickness of the beds which we include in the Middle Chalk at 40 metres (which is equivalent to 132 feet), assigning about 66 feet to each zone. In 1900 Dr. Rowe found it impossible to take any measurements at Lulworth.

In Man-of-War and Durdle Coves the chalk is inverted, crushed, and compressed to such an extent that the beds cannot be measured, and the cliffs are only interesting as affording examples of slide-planes and other incidents of overthrust faulting (see Fig. 75) for an account of which the reader is referred to Mr. Strahan's Memoir.

Whitenose, or White Nothe, is the next point at which a complete section through the Middle Chalk is displayed, and some account of it was given by Professor Barrois in 1876 (Recherches, p. 79). He was then able to ascend the cliff by a path which no longer exists, and which led up to the Coastguard Station.

The beach on the east side of the promontory is only accessible by boat, and on the west side there is a slope of landslips. The Chalk is dipping eastward at angles of from 5° to 8°, and Mr. Strahan states that the basement-bed rises from the beach about 300 yards east of the ledge formed by the Chert Beds near the point and reaches the top of the cliff 280 yards east of Holworth House, while the bed taken by him at the Chalk Rock rises about 740 yards east of the ledge and reaches the top of the cliff 600 yards west of the Coastguard Station.

The beds at the junction of the Middle and Upper Chalk appear to be variable in their aspect at this locality, for Mr. Strahan gives detailed descriptions of them at two different spots, which differ considerably from one another, and neither of them agree with Professor Barrois' account. The following are the particulars given by Mr. Strahan of the beds seen in a fallen mass on the east side of White Nothe point.

		feet.
	Chalk with flints ; a tabular mass of flint (2 to 6 inches thick) at the bottom	
Middle Chalk.	Nodular chalk with a few scattered flints	15
	Two layers of green-coated nodules separated by nodular chalk	1½
	Nodular chalk	2½
	Smooth white chalk with an occasional flint	6
	Chalk with wavy laminæ of dark marl	6

This series of beds seems to correspond very closely with that seen in Mupe Bay, the tabular flint occurring at exactly the same

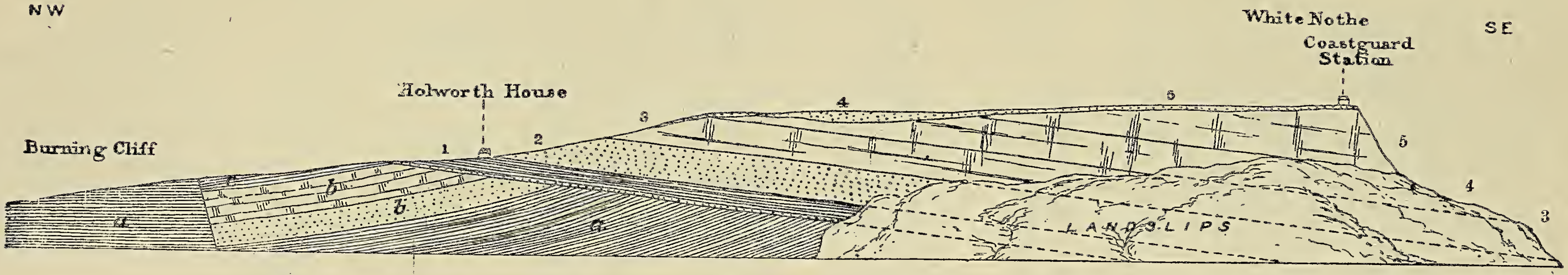


FIG. 77.—Section through Holworth House and White Nothe, Dorset (after A. STRAHAN).*

Scale, horizontal and vertical, 8 inches to a mile, or 660 feet to an inch.

5. Upper Chalk.
4. Middle Chalk
3. Lower Chalk.
2. Upper Greensand.
1. Gault.

c. Purbeck Beds.
b. Portland Beds.
a. Kimeridge Clay.

The Lower Chalk should have been drawn less thick (70 feet) and the Middle Chalk thicker (134 feet).

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* Reduced from Plate IX. in "Geology of the Isle of Purbeck and Weymouth."

height above the layers of green-coated nodules, so that probably this flint band should be taken as the real base of the Upper Chalk.

Dr. Rowe visited the locality in 1899, and found no difficulty in getting access to the whole of the Middle Chalk on the eastern side of White Nothe, or in estimating the thickness of each zone, but his prime object being to distinguish the zones he does not give complete stratigraphical details. He describes the zone of *Rhynchonella Cuvieri* as consisting of hard nodular chalk, and makes its thickness, measured up to the first line of flints, 76 feet. His zone of *Ter. gracilis* comprises first some thickness of "less nodular" chalk, with frequent marly layers, then a band of nodular chalk about 5 feet thick enclosing layers of green-coated nodules, and finally a certain thickness of nodular chalk. The total thickness of the zone is given as 58 feet, this being measured up to a certain layer of marl, above which the fauna of the *Holaster planus* zone comes in.

Combining this information with Mr. Strahan's note of the fallen mass it would seem that the succession at White Nothe may be formulated as follows:—

		feet.
Upper Chalk.	Zone of *Hol. planus.*	
Middle Chalk.	Nodular chalk with a few scattered flints - - -	15
	Nodular chalk with layers of green-coated nodules - -	5
	Smooth chalk with occasional flints, passing down into rougher chalk with a layer of flints at the base - -	38
	Zone of *Rhynch. Cuvieri*; hard nodular chalk without flints	76
		134

Most of the accessible portions of the cliff are much battered by the waves, but from a bluff of the chalk above that with the green nodules, Dr. Rowe obtained a fair number of fossils.

FOSSILS FROM THE MIDDLE CHALK OF SOUTH DORSET.

In the following list of fossils those collected by Mr. J. Rhodes are indicated by the letter x, those recorded only by Dr. Rowe by the letter R, and a few found only by Professor Barrois by the letter B.

——	Zone of *Rhynch. Cuvieri.*	Terebratulina zone.	
		Below green nods.	In & above green nods.
Pisces.			
Ischyodus sp. - - - - - -	–	B	–
Ptychodus sp. - - - - - -	–	–	x
Cephalopoda and Gasteropoda.			
Ammonites [Acanth.] Cunningtoni, *Sharpe.*	x	–	–
,, [Pachydiscus] peramplus, *Mant.*	x	–	–
Solariella gemmata *Sow.* ("Turbo") -	–	–	x
Lamellibranchiata.			
Inoceramus Brongniarti, *Sow.* - -	x	x	x
,, Cuvieri, *Sow.* - - -	–	x	R
,, mytiloides, *Sow.* - - -	x	R	–
Lima Hoperi, *Sow.* - - - - -	–	–	B
,, semisulcata, *Nilss.* - - - -	–	x	–
Ostrea curvirostris, *Nilss.* - - -	x	–	–
,, hippopodium, *Nilss.* - - -	x	R	R
,, normaniana, *d'Orb.* - - -	x	R	R
,, vesicularis, *Lam.* - - - -	–	x	–

———	Zone of *Rhynch. Cuvieri.*	Terebratulina zone.	
		Below green nods.	In & above green nods.
Pecten cretosus, *Defr.*	–	–	R
Spondylus dutempleanus, *d'Orb.*	–	–	–
„ latus, *Sow.*	–	x	R
„ spinosus, *Sow.*	–	x	x
Teredo amphisbæna, *Goldf.*	–	–	x
Brachiopoda.			
Rhynchonella Cuvieri, *d'Orb.*	x	x	x
„ plicatilis, *Sow.*	x	x	x
„ reedensis, *Eth.*	R	R	R
Terebratula biplicata, *Sow.*	x	–	x
„ carnea, *Sow.*	R	?	x
„ semiglobosa, *Sow.*	x	x	x
Terebratulina gracilis, var. lata, *Eth.*	x	x	x
„ striata, *Wahl.*	–	x	x
Bryozoa.			
Eschara Lamarki, *Hag.*	–	–	R
Diastopora Oceani, *d'Orb.* (Reptelea)	–	–	R
Homœosolen ramulosus	–	–	R
Membranipora sp.	–	–	R
Annelida.			
Serpula ampullacea, *Sow.*	–	R	–
„ annulata ? *Reuss*	–	–	x
„ ilium, *Sow.*	–	–	R
Echinodermata.			
Bourgueticrinus sp.	x	x	–
Cardiaster sp.	R	–	–
Cidaris clavigera, *Kœnig*	–	–	x
„ hirudo, *Sorig.*	R	R	–
„ serrifera, *Forbes*	R	–	R
Cyphosoma radiatum, *Sorig.*	–	–	x
Discoidea Dixoni, *Forbes*	x		x
„ subuculus ? *Klein*	x		–
Echinocorys scutatus, *Leske*	–		B ?
Galerites castanea, *Brongn.*	R	–	–
„ subrotundus, *Mant.*	x	x	x
Hemiaster minimus, *Ag.*	x	R	–
Holaster planus, *Mant.*	–	–	x
Micraster corbovis, *Forbes*	–	x	x
„ Leskei, *Desm.*	–	B ?	x ?
„ præcursor, *Rowe*	–	R	–
Ophiura sp.	–	R	–
Pentacrinus Agassizi, *Hag.*	–	–	R
Salenia granulosa, *Forbes*	–	R	–
Actinozoa			
Parasmilia sp.	–	–	x
Spongida		–	
Cliona cretacea, *Portl.*	R	R	
Craticularia Fittoni, *Mant.*	R	R	–
Guettardia stellata, *Mich.*	–	R	–
Plocoscyphia convoluta, *Smith*	R	–	R
Porosphæra globularis, *Phil.*	x	x	x
„ urceolata, *Phil.*	x	–	–
Ventriculites cribrosus, *Phil.*	–	R	–
„ mammillaris, *Smith*	–	–	R
„ radiatus, *Mant.*	–	–	R

CHAPTER XXXIII.

THE MIDDLE CHALK IN THE INLAND PARTS OF DORSET, SOMERSET, AND DEVON.

The Chalk areas of Dorset, Somerset, and Devon, once of course a continuous tract, are broken up toward the west into a series of outliers, and the Middle Chalk does not enter into all of these, though it occurs in all three counties. Thus they may be conveniently treated in one chapter, but we shall keep the account of the Dorset areas separate from that of those in Somerset and Devon.

North and West Dorset.

The main outcrop of the Middle Chalk enters Dorset about two miles south of Shaftesbury, passes southward along the slope of the escarpment to the valley of the Stour at Stourpaine and thence westward as far as the Chalk extends through the country. Along the northern side of the Dorchester basin, however, it often occupies the top of the escarpment ridges, passing thence into the valleys which drain southward and running down them for several miles before disappearing beneath the Upper Chalk.

Its thickness in the northern part of the county is about 100 feet, and about the same in the west on Toller Downs, but near Maiden Newton it appears to be rather less (? between 70 and 80.)

Melbourn Rock of the usual character continues to form the base of this division as far as Melcombe Bingham, but west of that a bed of hard smooth chalk comes in between the Belemnite marls and the base of the Melbourn Rock. This thickens to the westward, and swells out in places to 12 or 14 feet, the Melbourn Rock at the same time losing its specially massive and rocky character and becoming merely a rather hard nodular chalk. The smooth chalk is evidently the equivalent of that which occupies the same position in South Dorset.

Good exposures are not very numerous, and we shall mention such as exist, taking them from east to west, without sub-division into zones.

Stratigraphical Details.

The outcrop of the Melbourn Rock can be found in many of the roadways leading up the slope of the escarpment between Melbury Hill and the valley of the Stour. It is well exposed in the road east of Sutton Waldron at a height of about 450 feet above O.D., hard nodular rock with greenish stains resting directly on a thin layer of buff-coloured marl and overlain by solid white limestone with few nodules. The upper part of it, passing up into yellowish nodular chalk containing *Inoceramus mytiloides*, can also be seen in a quarry in the plantation a quarter of a mile east of Shroton church.

The best section, however, in this district is in a quarry about a third of a mile south-south-east of Okeford Fitzpaine, and it is remarkable as exhibiting a conglomeratic bed at the top of the Melbourn Rock. The beds seen are :—

		ft.	in.
Middle Chalk.	Hard white chalk, much broken, shaly at the base	6	0
	Hard yellow conglomerate (6 inches), consisting of chalk pebbles in shelly calcitic matrix, passing down into hard rough nodular chalk	3	0
	Several beds of firm white chalk, with hard yellowish nodules, separated by layers of grey shaly chalk	5	0
	Very nodular hard chalk	1	3
	Loose nodular chalk between two layers of grey shale	0	9
	Massive rough and hard nodular chalk, with yellow stains round the nodules	4	0
Lower Chalk.	Smooth bedded chalk	0	9
	Thin layer of grey marl	0	3
	Blocky greyish-white chalk	8	0
		29	0

The Middle Chalk crops out again on the southern side of Okeford Hill and forms an inlier in the Turnworth Valley, which runs southward to and beyond Houghton Winterborne, where *Inoceramus mytiloides* has been found by Mr. Mansel Pleydell.

To the south-west, between Milton Abbas and Alton Pancras, its boundaries have been mapped by Mr. C. Reid, and are shown on the recently issued map (Sheet 328, New Series). Its outcrop lies for the most part along steep slopes and nowhere occupies any great breadth of ground.

The following information is from notes supplied by Mr. Reid* : The ridge between Hilton and Melcombe Bingham is capped by Middle Chalk, which is exposed in a large quarry by the road-side half mile north-east of Melcombe ; here about 30 feet of nodular chalk (including the Melbourn Rock) rests on smooth (Lower) chalk.

In the Plush and Piddletrenthide Valleys the Middle Chalk occupies a rather wider space, and is exposed in several sections at the latter place ; north-east of the church a pit shows 35 feet of hard chalk, with a foot or two of yellow rocky chalk at the top, which is probably not far below the Chalk Rock.

The Melbourn Rock, underlain by a two-foot bed of smooth yellowish chalk, is exposed in a lane half a mile north of Alton Pancras and again in the lane south of Bookham (see p. 115).

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*See also " The Geology of Dorchester," Mem. Geol. Survey, by C. Reid, 1899, p. 8.

In the Cerne Valley the Middle Chalk occupies a narrow band on the steepest part of the slope on each side of the valley from Nether Cerne northwards. It rises gradually to higher levels till it comes to form the upper part of the high ridges which form promontories on both sides of the northern entrance to the valley. Here, however, its surface is concealed by the overlap of the Clay with flints.

Its thickness is still about 100 feet, and the hard rocky beds at its base and summit can be readily traced along the valley sides, but exposures of any depth are few. The lowest beds can be seen in the quarries on Giants Hill near Cerne, but are much weathered and partly covered by talus. At the base are 4½ feet of smooth streaky yellowish-grey chalk, hard at the top but softer below. This is succeeded by beds of rough whitish and somewhat nodular chalk, alternating with bands of soft grey marl enclosing small lumps or nodules of white chalk. The harder beds average 18 inches in thickness, the marl beds from 3 to 12 inches, and the whole is between 7 and 8 feet thick overlain by white chalk, which breaks into small angular pieces.

In the valley of the Frome the basset surface of the Middle Chalk forms a continuous tract along the eastern side from the hill above Frome St. Quentin to Crockway, between Maiden Newton and Frampton. Its thickness here is less, not more than 80 feet intervening between its base and the lowest bed of Chalk Rock.

It forms a similar narrow band on the flanks of the hills south and west of Maiden Newton, running into and all round the Wynford and West Compton Valley.

At Cruxton the lower beds are exposed in two small pits south of the farmstead. The lower one shows the following beds :—

	feet.
Hard white chalk, weathering into large lumps, but not nodular - - - - - - - - - - - -	3
Layer of soft marly chalk, about 4 inches.	
Hard nodular rock, weathering into nodular lumps, some of which are green-coated - - - - - -	4
Hard nodular rock, with *Rhynchonella Cuvieri*, marked off by divisional planes above and below - - -	3½
Hard rocky chalk, with a few green-coated nodules -	1
Hard white blocky chalk seen for - - - - - -	7

The two beds of nodular rock (7½ feet) seem to represent the Melbourn Rock. Thinking the soft grey Belemnite marl could not be far below the floor of the quarry, I had a hole sunk, but this was dug 5½ feet in hard white chalk without reaching it. At 2 feet down the base of a bed was nodular and had some fossils, *Rhynchonella Cuvieri* and an obscure fragment of an Ammonite, but nothing which was conclusive as to the zonal horizon of the material. There is here more than 13 feet of firm bedded white chalk below the nodular chalk of the *Rhynch. Cuvieri* zone.

The upper pit is a shallow one, only showing about 6 feet of yellowish nodular chalk with *Inoceramus mytiloides*.

The cart track which leads up to Hill Barn from near the upper pit is cut somewhat into the hill, and the following ascending succession can be traced, starting from about 5 feet above the level of the pit, but the thicknesses given are approximate only :—

		feet.
Chalk Rock and Upper Chalk.		
Hard greyish nodular chalk, with *Holaster planus* and *Terebratula semiglobosa* - - - - - - -	about	6
Layer of soft grey marl.		
Smooth blocky chalk, *Terebratulina gracilis* var. *lata*	,,	2
Loose chalk, with hard nodular lumps and a yellowish rocky bed in the middle, *Spondylus spinosus* - - -	,,	2½
Bedded chalk full of *Terebratulina* - - - -	,,	1½
Whitish lumpy chalk passing up into greyish nodular chalk with *Rhynchonella Cuvieri* - - - - - -	,,	4
Greyish-white chalk - - - - - - - -	,,	1
Hard nodular chalk with yellow stains - - - - -	,,	1
Soft chalk full of *Terebratulina* with also *Terebratula semiglobosa* and small *Rhynchonella Cuvieri* - -	,,	10
Soft greyish chalk, enclosing harder lumps - -	,,	5
		33

The *Terebratulina* zone is evidently full of its two most characteristic fossils at this locality, and it appears to be only about 33 feet thick, but probably the beds seen have slipped somewhat down the slope over the *Rh. Cuvieri* zone; of the latter, the apparent thickness is more than 35 feet; in all probability there is at least 80, and possibly 90, feet of Middle Chalk here.

The Melbourn Rock is seen in the limekiln at Shatcombe, 2 miles south-west of Maiden Newton, where the succession is as follows :—

		feet.
Middle Chalk	Rough nodular chalk - - - -	8
	Beds covered by talus - - - -	4
	Hard smooth whitish chalk - - -	4
Lower Chalk	Belemnite Marl - - - - - -	5
	Firm greyish blocky chalk - - -	5

In the outlying tract of chalk, which lies between the valley of the Frome and the head of the Axe Valley north-west of Beaminster, Middle Chalk occupies a considerable area, but is in most places covered and concealed by the "Clay with flints."

The section at the top of the large quarry west of Maiden Newton has been given on p. 115.

In the wood south-west of Higher Wraxall, and north-west of Maiden Newton, there is a quarry about 100 feet above the base of the chalk, and consequently at a level where the junction of Lower and Middle Chalk should be exposed. The beds seen are as follows :—

	feet.
Gravelly soil.	
Hard nodular shelly chalk with *Inoceramus mytiloides* -	5
Hard chalk, nodular at the top, but passing down into tough smooth blocky chalk - - - - - - - - -	10
Greyish-white chalk, rather loose and full of small rounded nodules of whiter chalk, base hidden by talus; seen for about	10

There was no sign of the Belemnite Marls anywhere, nor could I find any fossils except the one mentioned. The succession recalls that of Cruxton.

Near Pinnys Toller, or Toller Whelme, as it is called on the new Ordnance maps, the whole thickness of the Middle Chalk comes out from beneath the capping of clay with flints, and parts of it are exposed in old quarries by the main road north of Toller leading to Hill Barn. On the right hand side of the road, just above the 600 feet contour, hard nodular chalk, which resembles weathered Melbourn Rock, overlies softer blocky chalk. At about 650 feet is a quarry in firm, homogeneous white chalk, with small *Rhynchonella Cuvieri* and *Terebratulina gracilis* var. *lata*, while just at the 700 feet contour are old quarries in Chalk Rock, so that here there seems to be nearly 100 feet of Middle Chalk.

No good exposure of Middle Chalk was found north of Beaminster, nor near Cheddington, but the base of the division was seen in a quarry near Corscombe (see p. 117).

SOMERSET AND DEVON (INLAND).

The outliers of Chalk which occur near Crewkerne and Chard, and the others further west between Chardstock and Honiton, have been mentioned on p. 117. Several of these tracts are capped by still smaller outliers of Middle Chalk. Thus between Crewkerne and Chard there is a small tract of this chalk on Lady's Down, its base occurring at a height of about 730 feet; and there is another north of Cricket St. Thomas brought in by a fault which has a downthrow to the west of 60 or 70 feet.

South of Chard are two small tracts of Middle Chalk, each of them being faulted down on two sides against Lower Chalk, and on the hill west of Chard is an outlier about 1¼ mile long by three-quarters of a mile wide. Near Combe St. Nicholas is a small triangular tract of Middle Chalk and Chalk Rock let down into the valley far below its normal level between three lines of fault, the vertical displacement on its eastern side being over 300 feet.

On the high ground north-west of Combe there is another area of Middle Chalk which probably occupies some space, though it is partly covered by clay with flints. It caps an outlier of Lower Chalk, and also includes a tract of Chalk Rock, the base of which runs from 800 to 730 feet above sea level.

Near Membury, north of Axminster, a powerful fault lets in a long narrow tract of Chalk, part of which consists of the Middle division.

Lastly, near Widworthy, east of Honiton, another tract of such chalk is brought in by a similar fault, and this consists entirely of Middle Chalk resting on the arenaceous representative of the Lower Chalk or Cenomanian.

The chalk seen at the places above mentioned includes representatives of the zones of *Rhynchonella Cuvieri* and *Terebratulina*.

The total thickness existing at any place is probably not more than 80 feet, but no actual measurements could be obtained.

It will be convenient to describe first the sections near Crewkerne and Chard, then those at Membury, and finally that near Widworthy.

Crewkerne and Chard

There are no good sections between Crewkerne and Chard, though the road cutting on St. Rayn Hill must originally have shown a clear face of this zone and its junction with the Lower Chalk. Hard nodular chalk, like Melbourn Rock, can be seen in the bank at a level of between 730 and 740 feet, and higher up there is some tough yellowish-white chalk mottled with grey, containing many *Inoceramus mytiloides;* still higher there is firm, compact white chalk.

On Snowdown Hill, west of Chard, the Middle Chalk is at a high level, its base being probably at about 660 feet, and the top of the hill being over 700 feet. On the western slope of the hill and at a lower level there is a larger area of Middle Chalk brought in apparently by a fault which runs nearly north and south.

On the south side of the main road, where the surface level is about 630 feet, is a large old quarry. It is not now worked, and the only visible face showed about 15 or 16 feet of firm bedded chalk with several layers of nodular chalk and a few scattered flints, which are solid and black inside, with a thick rind. The nodular layers give a bedded appearance to the chalk, and one of them has a pink tinge in places. *Inoceramus mytiloides, Rhynchonella Cuvieri,* and *Terebratula semiglobosa* were common. Dr. Spicer, of Chard, also possesses a number of *Galerites subrotundus* which probably came from this quarry. Evidently the chalk here belongs to the highest part of the *Rhync. Cuvieri* zone, and it shows a slight dip to the south-east.

Further on, to the north of the road, and just below the 600 feet contour, is a smaller quarry in beds which are not far above the Melbourn Rock; near the top is a markedly nodular layer in which a very large Ammonite was embedded, broad and almost nautiloid in shape; around and inside this the chalk was brecciated or conglomeratic, like that at Okeford (see p. 425). *Inoceramus mytiloides* and *Rhynchonella Cuvieri* were also found here.

At White Staunton, 3 miles north-west of Chard, a small tract of chalk is faulted down between tracts of Upper Greensand, and a quarry in this south of the church shows a few feet of firm white chalk with some nodular lumps in the upper part. *Inoceramus mytiloides* is fairly common; two small *Rhynchonella Cuvieri* and an *Ostrea curvirostris* were also found, but no flints, so the horizon is probably about the middle of the *Rh. Cuvieri* zone.

South of Chard a tract of Middle Chalk comes in between Forton and Chardstock House. A quarry less than half a mile west of Forton exposes hard nodular chalk (apparently the top of the Melbourn Rock), passing up into looser nodular chalk which is crowded with shells of *Inoceramus mytiloides*. The outcrop of the rocky chalk makes a fairly-marked feature which can be traced southward toward Tatworth, and there is another large but rather shallow quarry opposite Tatworth vicarage, where 12 to 14 feet of similar beds are exposed, but in a more broken, weathered and rubbly condition. This chalk is cut off by a fault a little south of the quarry, which brings the Upper Greensand up to its level.

Middle Chalk, however, comes in again on the high ground north-east of Chardstock, and is exposed in a small pit on the east side of the lane about two-thirds of a mile north-east of the church. This exposure is small, but is noteworthy, because I obtained from it a specimen of *Am.* [*Acanthoceras*] *nodosoides,* a species which is not very common, and has only been found in the zone of *Rhynchonella Cuvieri.*

I did not find any exposure of chalk near Chard which I could refer with certainty to the *Terebratulina* zone, except on the hill north-west of Combe, where a pit shows the base of the Chalk Rock underlain by three feet of nodular chalk passing down into massive chalk. There are several small pits in the area west of Chard which expose soft white chalk possibly belonging to this zone.

Membury.

Another inland locality still further west where Middle Chalk occurs is Membury, a village about 4 miles N.N.W. of Axminster. Here in the lane west of the church and in the bank of a little garden hard nodular chalk like Melbourn Rock was seen, and just beyond is a quarry in the Middle Chalk containing *Rhynchonella Cuvieri, Terebratula semiglobosa,* and many fragments of *Inoceramus.*

In the next lane to the northward hard nodular chalk crops out at about 440 feet, chalk with *Inoceramus mytiloides* was seen at 470 feet, soft white chalk at 535, and hard lumpy chalk at about 555 feet; a piece of the last was sliced and examined by Mr. W. Hill, who reported that it resembled chalk occurring elsewhere just below the Chalk Rock. Clay with flints, however, comes on just above this point, and that Rock if present is concealed. The difference of level, however, seems to indicate a thickness of more than 100 feet for the Middle Chalk here, an increase of thickness, which is borne out by the coast sections.

By the next lane running north-west toward Furley there is an old quarry, at the top of which a few feet of rubbly chalk is exposed, containing *Inoceramus mytiloides* and *Rhynchonella Cuvieri.*

Widworthy and Wilmington.

The outlier west of Widworthy and the smaller one north of Wilmington are shown on the map (Fig. 30, p. 126), and the section in the sand-pit near Wilmington, showing the basement beds of the Middle Chalk, has been given on p. 127.

There are some old chalk quarries in the park east of Widworthy Court, and Mr. A. Marwood Elton, of the Court, informs me that freestone was quarried from them as well as from the Sutton quarries half a mile further south.

This freestone is a bed in the lowest part of the Middle Chalk, and is apparently identical in character and position with that occurring at Beer, near the coast, and known as Beer Stone. It consists principally of small fragments of shell set in a chalky matrix, and cemented by calcite into a hard, gritty stone, which cuts freely in any direction when freshly quarried.*

No exposure of the freestone was visible when I visited Widworthy in 1897, but I was informed by a mason (Mr. D. Hooper) who had worked in the large Sutton quarries that the succession of beds there was as follows:—

		feet.
Flint rubble at the top		4–6
Soft white chalk		10–30
Hard chalk	about	20
Freestone	,,	5
Soft chalk with green grains	,,	5
Hard cockly chalk	,,	2
Grizzle at the bottom (see p. 126).		

A foot or two of the soft white chalk could be seen near the top of the quarry above the limekiln, and had the character of the chalk of the *Terebratulina* zone. I had the talus cleared away from the lowest face of the quarry by the side of the limekiln, and disclosed about 18 feet of rather hard chalk, lumpy in places and containing *Inoceramus mytiloides*, mostly as broken shells; this evidently belonged to the zone of *Rhynchonella Cuvieri*, and in another part of the quarry Mr. Rhodes obtained that *Rhynchonella* with *Inoceramus mytiloides* from similar chalk.

The base of this hard chalk was not reached, as a large block of inferior freestone, a hard, shelly chalk, lay below, but this and the better freestone was probably in place near by.

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* Dr. Hinde has kindly made slides from samples of the Beer Stone and Sutton Stone which I sent to him, and has informed me that the two stones have the same microscopic structure (see p. 504.)

CHAPTER XXXIV.

THE MIDDLE CHALK OF THE DEVONSHIRE COAST.

General Description.

The outlying patches of Chalk which are intersected by the coastline of Devonshire include a considerable thickness of Middle Chalk. The fine cliffs of Pinhay and Whitlands, and the still bolder walls of Beer Head, consist almost entirely of this Turonian Chalk, for, as stated on p. 126, the representative of the Lower Chalk is in most places only a few feet thick. The Middle Chalk, on the other hand, is well developed and is actually thicker than it is in the west of Dorset, having near Beer a thickness of 140 feet.

The Zone of Rhynchonella Cuvieri varies much in thickness, being between 50 and 60 feet near Lyme Regis and 35 at Beer Harbour, thinning to only 15 at Beer Head and disappearing altogether for a space in Hooken Cliffs, where the *Terebratulina* zone rests directly on the coarse sandstone of the lowest Cenomanian stratum. The lower zone comes in again to the westward, however, and in Berry Cliff it regains a thickness of 38 feet. At Dunscombe it forms the most westerly patch of chalk in England.

There is no regular bed of Melbourn Rock at the base of the zone, the lowest bed being everywhere a hard, rough, gritty limestone containing grains of quartz and glauconite, but above this there is generally a bed of chalk full of hard yellowish nodules like those in Melbourn Rock. It is probably the equivalent of that rock in a looser and less consolidated form.

The Beer Stone is a local development of shelly chalk in this zone. Mr. Whitaker was the first to describe it as actually part of the Chalk, and Dr. Ch. Barrois was the first to recognise its true zonal position.

It is a remarkable fact that Micrasters are not uncommon in this zone in Devonshire, and Dr. Rowe informs me that both *M. corbovis* and *M. Leskei* are present.

The Terebratulina Zone.—This is the "Chalk with flints" of earlier writers and was supposed to be Upper Chalk simply because the flints are like those in the Upper Chalk; they are very numerous, occurring both in layers and as scattered nodules. The fossils, however, are quite decisive as to its true stratigraphical position, which was first recognised by Prof. Ch. Barrois in 1876.* It is a remarkable fact that this zone is thicker in Devon than it is in South or West Dorset, being near Beer about 80 feet thick and about 100 feet at Beer Head.

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*Recherches sur le Terrain Crétacé Supérieur, p. 72.

Mr. Meyer gave some description of the beds which are now classed as Middle Chalk in his paper on the Cretaceous Rocks of Beer Head.* In comparing Mr. Meyer's account of these beds with the more detailed sections which are given in the following pages, the reader will find that the zone of *Rhynchonella Cuvieri* includes his Beds 14, 15 and 16. The base of his 17 is marked by a layer of rather large black flints and this may be taken as the base of, the *Terebratulina* zone, which will then include Mr. Meyer's 17, 18, 19, and the lowest part of his 20. His highest bed (20) takes in all the rest of the visible "chalk with flints."

Stratigraphical Details.

Zone of Rhynchonella Cuvieri.

The lower part of this zone is well exposed at the eastern end of Pinhay cliffs. The higher beds are partly obscured by grass and talus and are difficult to reach, but by piecing together small exposures the following descending succession was made out, the thicknesses assigned to the beds being only rough measurements, by eye and hammer:—

	ft.	in.
9. Firm whitish chalk, massive, without flints, full of broken *Inoceramus* shells - - - about	15	0
8. Soft yellowish dusty chalk - - - - - - -	5	0
7. Rather hard yellowish chalk - - - - - -	10	0
6. Whitish chalk, enclosing large nodules of hard yellowish chalk and some small flints - - - - - -	1	0
5. Whitish chalk, exposed as a bare face, with a few small scattered yellow nodules - - - - - - -	11	0
4. Massive whitish chalk, forming a vertical wall, no nodules - - - - - - - - - - -	16	0
3. Hard yellowish chalk, full of small hard nodules - -	2	0
2. Very hard yellowish-white limestone - - - - -	1	0
1. Very hard chalky limestone, with many grains of quartz and glauconite, especially in the lower part -	1	4
Cenomanian.—Rubbly and sandy rock, consisting of quartz and glauconite grains in a chalky paste, with hard lumps and derived phosphate nodules near base - - - - - - - - -	0	10
About	63	0

Very few fossils were found here; the lowest bed passes up into the next (No. 2), which contains *Inoceramus mytiloides* and certainly belongs to the *Rh. Cuvieri* zone, as do all the succeeding beds up to the top of No. 7. The soft dusty chalk above this has the aspect of the *Terebratulina* zone, but the succeeding beds have the shelly character of the *Rhynch. Cuvieri* zone, so that it is difficult to say where the line should be drawn. If both these beds are excluded the thickness of this zone is about 43 feet, if they are included it is over 60 feet.

A clear vertical section of the whole zone can also be seen in the great cleft at the western end of Pinhay cliff, where a large mass or slice of rock has recently moved outwards without slipping far out of position. The difficulty of reaching this position prevented me from examining it; Dr. Rowe, however, measured it in 1898, and informs me that the *Rh. Cuvieri* zone has a thickness of 56 feet.

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*Quart. Journ. Geol. Soc., Vol. xxx., p. 369 (1874)

The same beds can be examined on the opposite side of the Whitlands valley at the south-west end of Lynch Plantation, 30 or 40 feet being seen, and consisting partly of loose and partly of massive chalk in alternating beds with many *Inoceramus mytiloides*; as before there is a glauconitic and quartziferous basement bed.

A fourth place where there is a clear and fairly accessible section of the *Rh. Cuvieri* chalk is below the Coast Guard station on Whitlands cliff. Here there seem to be 50 or 60 feet assignable to this zone, and the basement beds are well exposed in a sort of alcove at the bottom of the vertical cliff. The section here is as follows:—

	ft.	in.
Rough chalk, full of small chalk nodules - - -	6	0
Hard nodular quartziferous chalk, with *Rhync. Wiesti*, *Inoc. mytiloides* and *Discoidea Dixoni* - - -	1	9
Greenish sandy and glauconitic chalk, with some scattered phosphate nodules; *Actinocamax plenus* and *Am.* (*Douvilleiceras*) *euomphalus* - - -	0	9
Hard shelly limestone, with a layer of brown phosphatic nodules at the top - - - - - - - -	1	0
Selbornian. Hard calcareous sandstone.		

Though the fossils found in the lowest 9 inches of sandy glauconitic chalk link this rather with the Lower than with the Middle Chalk, it passes up into the hard quartziferous chalk.

At the corner of Charton cliff, a little further west, the base is again exposed, and the section, though small, is remarkable, for there is no Cenomanian limestone, and the quartziferous chalk rests directly on the topmost bed of the Upper Greensand.

Lower down, and a little to the eastward, a more complete section was found in a large fallen mass. This showed:—

	feet.
Firm shelly chalk, with hard yellow nodules standing out on the rough weathered face - - - - - - -	10
Hard rocky nodular quartziferous chalk, with a marked yellow layer at the top - - - - - - - -	2
Plane of separation with flattish lenticular lumps of phosphatic matter and a few nodules.	
Selbornian. Hard calcareous shelly sandstone - -	6

In the quartziferous and glauconitic chalk here I found *Inoceramus mytiloides*, *Cardiaster pygmœus*, *Discoidea minima*, and *Cidaris hirudo*, all Turonian species. Here, therefore, the Lower Chalk is absent, and the Middle Chalk has a glauconitic basement-bed.

Passing to Rousdon cliff, the lower part of the Middle Chalk is exposed in the bank by the roadway just above the old quarry, and the basal beds are exposed at the top of this quarry. By the roadway a specimen of *Am.* [*Acanth.*] *rusticus* was seen. From this point westward the chalk of the *Rh. Cuvieri* zone can be followed continuously in the cliffs for about a mile, but is not always accessible, except in the fallen masses.

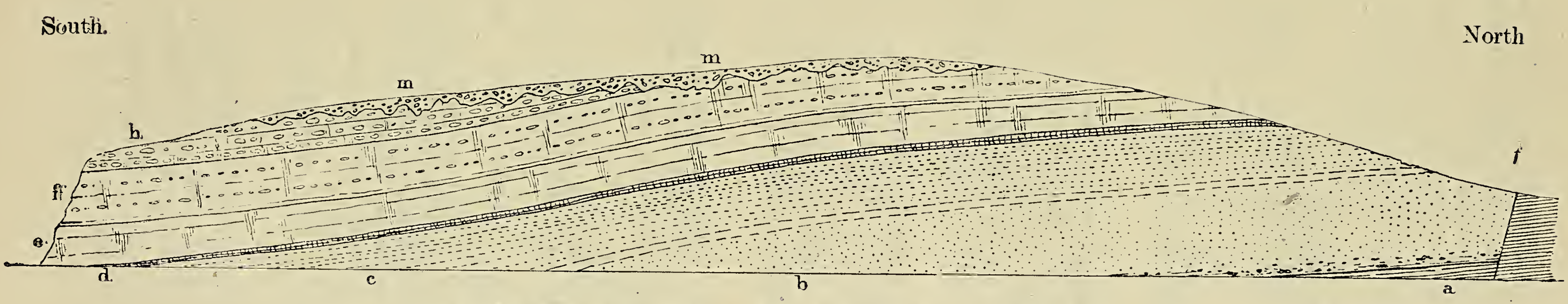

FIG. 78.—The section exposed in Whitecliff, west of Seaton.

Horizontal Scale about 80 yards to an inch. Vertical Scale 200 feet to an inch.

m Flint Gravel.
h Upper Chalk.
f *Terebratulina* zone } Middle
e Zone of *Rhynch. Cuvieri* } Chalk.
d Zone of *Am. Mantelli* (Cenomanian limestone).
c Chert Beds } Selbornian
b Grey and Green Sand } Selbornian
a Red Marl (Triassic).
f Fault.

In the cliffs of the great landslip at Bindon it is again well exposed, and is very accessible on the south side of the great gap. Here the following succession was measured :—

	ft.	in.
Firm white chalk with frequent vertical joints, several *Rhync. Cuvieri* - - - - - - - - - -	9	0
Firm white chalk, with a layer of black flints at the top and another at the base - - - - - - - -	8	0
Firm white chalk, weathering into rough blocks - -	9	0
Massive white chalk with even fracture - - -	3	6
Hard rocky nodular chalk with yellow lumps - - -	2	6
Firm white smoother chalk with some small scattered nodules - - - - - - - - - - -	6	0
Loose nodular chalk, with many yellowish nodules of various sizes, passing into next - - - - -	9	0
Hard quartziferous and glauconitic chalk - - -	1	6
	48	6

Here there is a complete passage from a pure chalk down into the glauconitic basement bed, which also is thinner than usual.

At the west end of the landslip the basal bed, about 2 feet thick, separates itself from the chalk above, and contains *Rhynchonella Wiesti* in some abundance. Above it about 20 feet of nodular chalk is exposed.

The most complete and most accessible section of this zone, and of the whole of the Middle Chalk in Devon, is that in the cliffs above Beer Harbour (see Figs. 78 and 79). The lowest beds are found at the southern end of Whitecliff, and as they are most conveniently examined in ascending order I give the succession in that way :—

	feet.
1. Very hard rough nodular yellowish-white limestone, containing scattered grains of quartz and glauconite, especially at the base, which is clearly separated from the bed below (see p. 131) - - - - - - -	3
2. Hard yellowish nodular chalk - - - - - -	6
3. Less hard chalk with grey streaks and few nodules, in two beds, with a marked plane of separation (? represents Beer Stone) - - - - - - - -	5
4. Rough nodular chalk, with a course of very hard yellowish nodules at the base - - - - -	9
5. Nodular chalk, with a course of hard yellow nodules at the base and a few scattered flints near the top -	8
6. Hard nodular chalk, with greyish streaks, and some flints and a layer of yellow nodules at the top - - -	1
7. Hard white chalk with grey streaks, and flints and a layer of yellow nodules at the top - - - - -	2½
8. Softer whitish chalk, with a layer of black flints at the base, a few scattered flints and a layer of yellow nodules at the top - - - - - - - - - -	7½

I take No. 7 to be the top of the zone of *Rhynchonella Cuvieri*, though some might prefer to extend it to the top of No. 8. Omitting it, the thickness of the zone is nearly 35 feet at Whitecliff.

The basement bed in the above section is that which Mr. Meyer indicated by the number 14 in his account of the Cretaceous

Rocks at and near Beer Head. Common fossils in this bed are: *Cardiaster pygmæus*, *Cidaris hirudo* (spines), *Discoidea Dixoni*, *Hemiaster minimus*, and *Rhynchonella Cuvieri*.

The next bed (6 feet thick) does not appear in Mr. Meyer's account, but we agree in making the representative of the Beer Stone to be 5 feet thick; this bed however differs from the freestone of the Beer quarries, which will be described later on. From these two beds (2 and 3 of my section) *Inoceramus mytiloides*, *Rhynchonella Cuvieri*, *Cidaris hirudo*, *Discoidea Dixoni*, *Hemiaster minimus*, *Galerites subrotundus*, and a palate of *Pycnodus* were obtained by Mr. Rhodes and myself.

The succeeding 20 feet contain the same and a few other fossils; they constitute Bed 16 of Mr. Meyer, and the thickness of 8 feet given by him is probably a misprint for 18 feet.

The highest bed of my section (No. 8) is clearly No. 17 of Mr. Meyer, but few fossils can be found in it at Whitecliff or Beer, and I prefer to regard it as the base of the *Terebratulina* zone.

The same succession can be examined on the other side of Beer Harbour, south of the gap, where a longer extent of the lower beds can be reached. The basement bed can be seen to decrease in thickness from 2½ to 1 foot, the overlying bed being only 4 feet and the Beer Stone only 3 feet at the same place. The total thickness of the zone here is not more than 30 feet. The basement bed at this place yielded the same fossils as before, together with *Galerites subrotundus*, while in the bed above I found *Micraster corbovis* (a very low horizon for this species), *Cardiaster pygmæus*, and *Discoidea Dixoni*. *Cardiaster pygmæus* is common in these beds all along the coast, and runs to an unusually large size, some specimens being more than an inch in length.

The next point at which the zone of *Rhynchonella Cuvieri* can be conveniently measured is at the caves to the north of Pounds Pool. Here the beds dip into a slight syncline before rising into the anticline above Pounds Pool beach, and it is the hard chalk of this zone which forms the buttresses of the caves. The following descending succession can be seen, beginning below a conspicuous layer of black flints:—

		feet.
7 & 8.?	Chalk with scattered flints - - - - - -	2
5 & 6.	Massive streaky chalk with scattered flints, a layer of hard yellow nodules at the top and some nodules below; marked plane of separation at base - -	5
4.	Hard nodular chalk, yellow and rocky at top, and another layer of yellow nodules at base, *Inoceramus mytiloides* - - - - - - - - - -	4
2 & 3.	Rough nodular chalk (6 inches), passing into streaky chalk with few nodules, with rough nodular chalk again below, *Inoc. mytiloides*, *Rhync. Cuvieri*, *Cardiaster pygmæus* - - - - - - -	7
1.	Hard rough yellowish nodular limestone, with green grains in lower part - - - - -	2
		20

Here every bed except the basement is still further condensed, and the thickness of the zone is much less than it is near Beer; moreover, southward, above the beach, the middle part of the 7-foot bed can be seen to thin out, the total thickness being thus further diminished. The streaky chalk seems to represent the Beer Stone.

At Beer Head the chalk of this zone can be reached again in a small gully above the fallen blocks a little west of the headland itself, and here the thickness is still further reduced, the succession being as follows:—

		ft.	in.
	Soft white chalk with layers of black flints.		
Zone of *Rhynch. Cuvieri.*	Soft chalk without flints	1	6
	Hard solid yellow limestone, welded to the top of the bed below	0	6
	Rough nodular shelly chalk with *Cardiaster pygmæus*, *Discoidea Dixoni*, and *Cidaris* spines	6	6
	Hard nodular chalk, with a few scattered grains of glauconite	5	0
	Hard yellowish limestone with defined upper surface; contains much quartz and glauconite	1	9
		15	3

The basement bed here contains more quartz and glauconite than it does to the northward, and there are hollows filled with glauconitic sand between it and the bed below (see p. 134). There is nothing which can be identified as Beer Stone. Between the upper yellow limestone and the overlying chalk there is a marked plane of division, and this might be taken as the summit of the zone, but I take the next 18 inches to represent the highest 2-foot bed at Pounds Pool.

From this point toward the west and north-west the zone swells out again. The whole of it can be measured in the "Pinnacles," which are huge detached masses which have slipped from the eastern end of Hooken cliffs, and are part of the great landslip of 1790. Here the basement bed has the same thickness as at Beer Head, but it rests on a bed of chalky glauconitic sand (see p. 133), and is overlain by 7 feet of very gritty, yellowish-grey chalk, succeeded by about 12 feet of rough nodular chalk, including a bed of hard yellow compact limestone at the top, 9 inches thick. Here, therefore, the zone is 20 feet thick.

The next point where these beds can be reached is in the cliff below the coast-guard station by means of the long talus slope mentioned on p. 135. It was at this place that Mr. Meyer took the section on which he based his paper. The following are the beds which seem to be referable to the zone of *Rhynch. Cuvieri*, and the prefixed numbers refer to those in Mr. Meyer's succession:—

		feet.
	17. Compact streaky chalk, with a few scattered flints and a layer of flints at the base	6
Zone of *Rh. Cuvieri.*	16. Rough chalk full of hard lumps, but with 12 inches of streaky chalk in the middle	13
	15. Compact even-grained streaky chalk; this seems to be the Beer Stone	6
	14. Hard nodular chalk, passing down into rough gritty chalk with hard lumps. I took *Galerites subrotundus* from the base of this	7

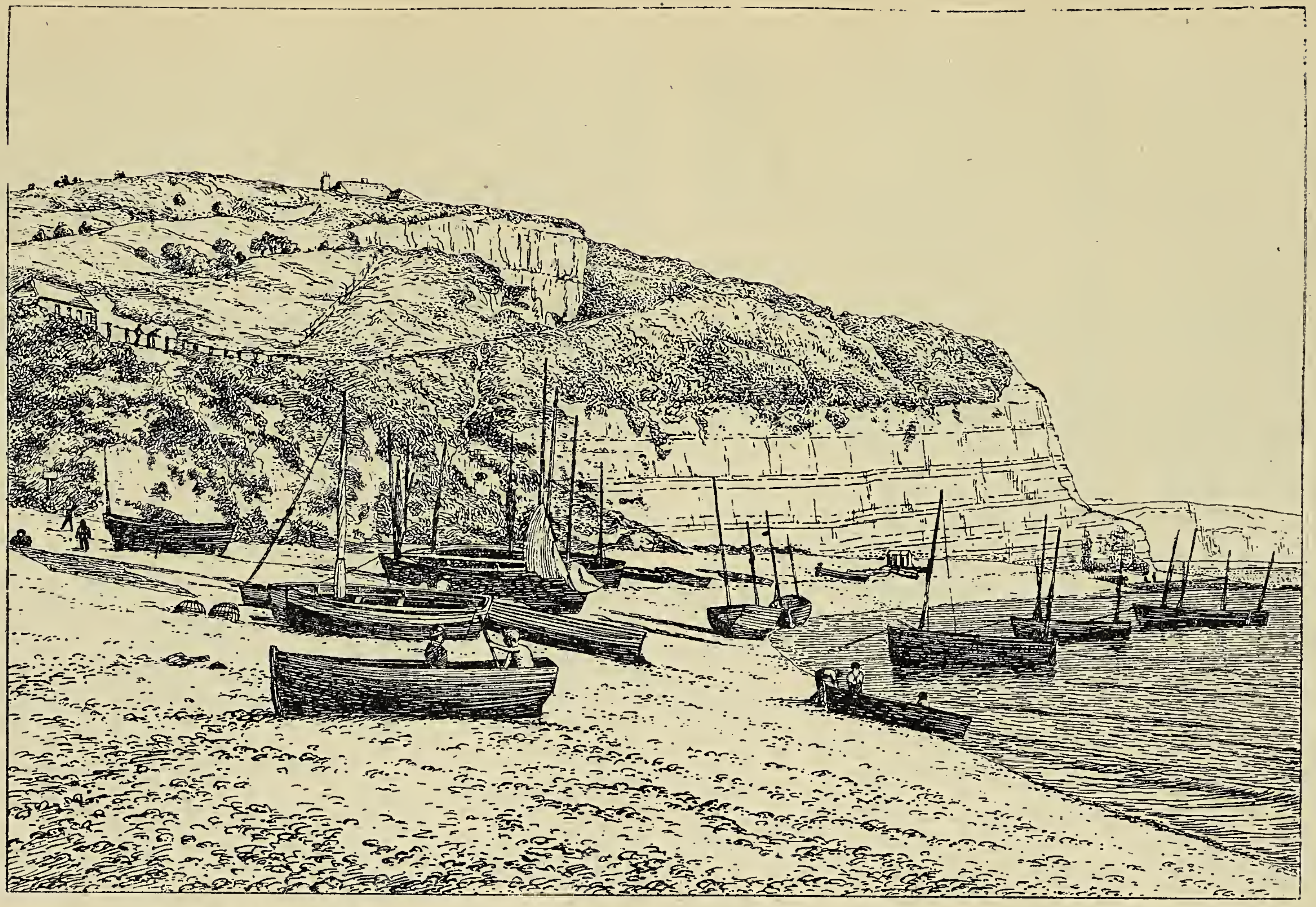

Fig. 79.—View of the Cliff on the north side of Beer Harbour, showing zone of *Rh. Cuvieri* at base, and that of *Terebratulina* above. The highest bluff is Annis' Knob, and consists of Upper Chalk.

The gritty chalk at the base contains glauconite grains, and passes down into the rough glauconitic sand with chalky matrix, which here forms a kind of passage bed between the Turonian and Cenomanian stages. It will be noticed that in the short distance between the Pinnacles and this cliff all the beds have thickened, and the total is 26 in place of 21 feet; also that the hard upper limestone of the Pinnacle and Beer Head sections is not here distinguishable, but its place is doubtless at the top of Mr. Meyer's No. 16.

Fig. 33 is reproduced from a photograph of the cliff where the above section was taken, and Mr. Meyer's numbers are marked on the beds in the middle of the cliff.

A little west of the talus slope, and in a re-entrant angle of the cliff, is an adit (visible in Fig. 33), whence Beer Stone was formerly extracted. Dressed blocks of the stone still lie about on the slope below, alongside the pathway leading down to the shore, where the stone was shipped, but since the making of the railway to Seaton this quarry has not been worked.

The Beer Stone is a bed of very local occurrence, hardly traceable as a freestone in Beer cliffs, as we have seen, but probably extending from the great quarries west of Beer in a southerly direction to this part of the cliffs.

From this point the zone we have been following rises high into the cliffs, and can be followed with the eye for some 200 to 300 yards; then it partakes in the rapid and remarkable thinning out of the Cenomanian, and is finally overlapped by the chalk of the *Terebratulina* zone (see Fig. 80). Nor, so far as can be seen does it come in again in any part of the cliff east of Branscombe Mouth.

It is not easy to ascertain exactly what happens in the Hooken cliffs, where certain beds thin out and disappear, because they are practically inaccessible; but so far as I could ascertain by scanning the lines in the cliff from below the disposition of the beds appeared to be as represented in Fig. 74. If my view of it is correct the phenomenon must be regarded as partly a case of contemporaneous erosion and partly one of thinning out of beds against a bank. I assume that originally the beds A and B were continued westward over the Selbornian, though possibly becoming somewhat thicker in that direction, and forming a kind of sand bank; then the sea floor seems to have been swept by a current which removed the material of B and nearly the whole of A from a portion of the area. It is difficult to understand how this tract continued to form a submarine bank, and yet, if we suppose that the zone of *Rhynchonella Cuvieri* was also continuous over the tract in question, we must assume another period of erosion after its formation, and the structure in the cliffs does not suggest any such second erosion. The beds, especially those of the *Terebratulina* zone, seem to come down and thin out against the Bed A as if against a submarine bank.

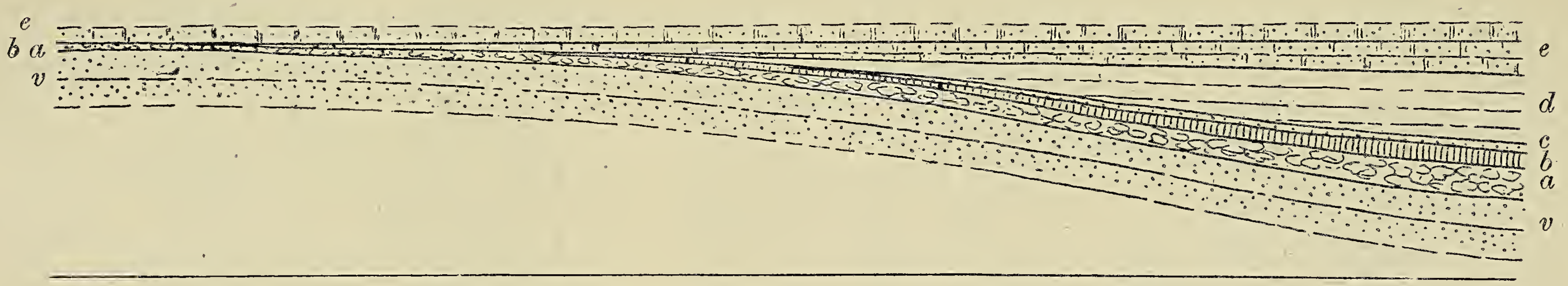

FIG. 80.—Diagrammatic View of a portion of Hooken Cliff.

Horizontal scale, 100 yards to an inch. Vertical scale, 120 feet to an inch.

e Zone of *Terebratulina.*
d Zone of *Rhynch. Cuvieri.*
c Sandy Glauconitic Chalk.
b & *a* Zone of *Ammonites Mantelli.*
v Selbornian Sandstone.

Inland, and about one mile west of the village of Beer, are large quarries where the Beer Stone has been worked for several centuries, at first by open quarrying, but more recently by means of adits driven into the hill. The open quarry is about 80 feet deep, and the upper beds were formerly burnt for lime. A good section through the lower half of the zone of *Terebratulina* and through that of *Rhynchonella Cuvieri* is here shown. The uppermost 30 feet is inaccessible, but the rest is easily measured and the whole section is as follows :—

			feet.
Terebratulina Zone.	Soil and broken chalk, with a few flints -	about	9
	Conspicuous layer of black flints.		
	Chalk with many courses of flints - -	„	24
	Chalk with few flints - - - - - - - -		6
	Chalk without flints - - - - - - -		3
	Soft white chalk with scattered flints and some in layers - - - - - - - - - -		8
	Soft smooth chalk (1 or 2 feet), passing down into rough nodular chalk, varying from 6 to 15 inches, *Galerites subrotundus* and *Rhynch. Cuvieri* - -		2½
Zone of *Rhynch. Cuvieri.*	Very hard compact yellowish limestone, passing down into hard shelly brecciated chalk (buff and white) ; *Rhynch. Cuvieri* and *Ter. semiglobosa* -		2
	Rough yellowish nodular chalk, rather coarse-grained and apparently consisting of comminuted shell fragments, *Inoceramus mytiloides* - - - -		11½
	Somewhat nodular chalk, like the last, called the " roof course " or " cockly bed " - - - -		3
	Compact crystalline freestone in thick beds - -		8
	Freestone in thinner beds and harder - - -		5
			82

The two lowest beds, with a combined thickness of about 13 feet, form the rock known as the Beer Stone or freestone of Beer. It is a granular limestone, consisting almost entirely of comminuted fragments of Inoceramus shells (see p. 506). From the freestone Mr. Rhodes obtained *Nautilus sp.*, *Inoceramus mytiloides*, *Ptychodus mammillaris*, *Rhynchonella Cuvieri*, *Galerites castanea*, *Hemiaster minimus*, and *Terebratula semiglobosa*.

It is quarried by adits, which now form a large subterranean cavern under the hill to the north. In former days still lower beds seem to have been exposed which are not now to be seen in this or in any of the older workings in the valley, of which there are several. A detailed account of the Beer Stone was published in 1826 by Sir H. de la Beche,* who says : "Beneath 18 feet of indurated chalk without flints, which they call 'skull,' the workmen enumerate eight beds." He gives a list of these beds which vary in hardness from soft to very hard, and have an aggregate thickness of 12 feet 4 inches. "Beneath these are about 5 or 6 feet of hard calcareous rock which burns into good lime, but is not quarried as the others are. Beneath this the sandstones commence."

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*Trans. Geol. Soc., Ser. 2, Vol. ii. p. 78.

Again, Mr. Whitaker, who visited the quarry in 1868,* gives the following account of the section:—

	feet.
Thickly-bedded massive (chalk), with a rough layer on top (mostly forming a hard even cap) - - - -	15 or more
Massive, more crystalline bed (Freestone) - about	10
More splintering, and with dividing lines of a darker tint - - - - - - - - - about	8
? Chalk Marl.—Bottom part with a few quartz grains and black grains.	

It is clear, therefore, that beneath the floor of the present quarry there are a few feet (probably 4 or 5) of hard and rough chalk with a basement bed containing quartz and glauconite. Probably these beds resemble those seen in the cliffs of Beer Harbour rather than those of Hooken cliff, but it would be interesting to know whether there is any representative of the calcareous greensand, No. 13 of Mr. Meyer's succession. The total thickness of the *Rh. Cuvieri* zone in Beer quarries may be set down at 34 or 35 feet.

The compact limestone which I take as the summit of the *Rh. Cuvieri* zone is a remarkably hard and compact rock resembling some varieties of Chalk Rock, it is thickest and best developed along the western face of the quarry, seeming to pass into a more nodular kind of rock toward the east. The beds have a dip of about 4° to the east.

The disappearance of the *Rhynch. Cuvieri* zone in the Hooken cliffs is quite a local phenomenon, for the beds set in again with their usual characters to the west of Branscombe Mouth. They can be reached in several places between a quarter and half a mile west of the Coastguard Station, and the following succession can be made out:—

		feet.
	Soft white chalk, with layers of flint nodules at intervals of 1 to 1½ feet apart (base of *Terebratulina* zone) - - -	15
Zone of *Rhynchonella Cuvieri*, 25 feet.	Hard rough chalk, very hard at top, with yellowish crystalline lumps throughout, *Cardiaster pygmæus*, *Ter. gracilis* var. *lata*, and *Cidaris Sorigneti* -	7
	Softer white chalk with few nodules, but with one layer of small flints, *Cidaris* spines - - -	8
	White chalk streaked with yellowish-grey, containing many small hard nodules and a layer of black flints - - - - - - - - -	4
	Rough yellowish chalk full of hard yellowish lumps, *Cardiaster pygmæus* and *Cidaris Sorigneti* - -	5
	Yellowish glauconitic chalk with some quartz-grains, *Ammonites* [*Prionocyclus*] *Neptuni*	1

The thickness of the zone here, therefore, is about 25 feet, so that it must come in again as rapidly as it thinned out. It will be noticed that the streaky chalk which appears to occupy the place of the Beer Stone contains a layer of flints, which thus occur much lower down than they do near Beer.

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*Quart. Journ. Geol. Soc., Vol. xxvii. p. 98 (1871).

The zone becomes still thicker to the westward, and the following section was measured near the beginning of Berry cliff about a mile and a quarter west of Branscombe Mouth:—

		feet.
	Soft white chalk, with frequent layers of flints and a layer of large flints at the base	
Zone of *Rhynchonella Cuvieri.*	Very hard compact yellow limestone	½
	Soft whitish chalk with flints, both scattered and in layers, many hard nodules and several nodular layers. Spines of *Cidaris Sorigneti* are abundant, *Rhynch. Cuvieri* and *Inoceramus mytiloides*	14
	Massive firm chalk with few nodules, but having lenticular lumps of very hard chalk, *Cidaris hirudo*, test and spines	10
	Rough nodular chalk in alternating layers of very hard nodular rock and less hard shaly chalk, *Cidaris hirudo*, *Cidaris Sorigneti* and *Discoidea Dixoni*	12
		36½

The actual base was not visible at this spot, but near by the basement bed was seen to be a foot thick and to be a very hard yellowish limestone with scattered grains of quartz and some glauconite at the base, which rests on and seems to enclose some of the phosphatic nodules at the top of the Cenomanian. The total thickness here is nearly 38 feet, this being more than at Hooken or even at the Beer quarries.

Lower down the slope and above "Red Rock" path are two fallen blocks, one of which shows the basement bed and the junction with the Cenomanian very clearly; the other is a mass of the upper part of the zone and is crowded with spines of *Cidaris*, especially the knob-headed *C. Sorigneti*, with *Cardiaster pygmæus*, *Discoidea Dixoni*, and *Rhynchonella Cuvieri*. The mass includes the thin limestone top covered by soft chalk with large black flints.

Another good exposure of this chalk occurs a little farther west above Donkey Linhay rocks, and the details are similar.

Beyond Littlecombe Hollow the chalk rises to the very summit of the cliffs, the higher part of which is here very steep and difficult of access.

The most westerly chalk tract in England is that on the summit of Dunscombe Hill between Weston and Salcombe mouths. It is quite inaccessible except by means of ropes and tackle, but above the Cenomanian limestones there can be seen 10 or 11 feet of rough nodular chalk resembling that of Berry cliffs, so that there can be no doubt that the zone of *Rhynchonella Cuvieri* is present.

The Terebratulina Zone.

The first exposure of this zone is in Pinhay cliff above the section of the *Rh. Cuvieri* zone described on p. 433. In the bluff above the slope where the section was taken about 20 feet of soft white chalk with many elongate and finger-shaped flints can be seen, but the higher beds are inaccessible. On the west side of this there is a small fault with upthrow to the west, and in the next bluff the following succession is seen:—

	feet.
Hard rocky chalk (Chalk Rock)	
Soft white chalk with a few flints, *Holaster planus* found near the top, and *Ter. gracilis* var. *lata* common throughout -	20
Soft white chalk in massive beds, with many finger-shaped flints - - - - - - - - seen for	10

The visible thickness of the zone is not more than 40 feet unless the 20 feet of underlying chalk without flints is included (see p. 433); but as there is a fault, and the beds cannot be measured in vertical succession, it is possible that there is more than 40 feet in the bluffs, and this suspicion is confirmed by what is seen further west.

The upper beds of this zone are seen at the base of the bluff which is known as Chapel Rock.

The whole zone and that of *Rhynchonella Cuvieri* are exposed in the great cleft formed by the breaking away of a large slice of the cliff at the west end of Pinhay cliffs. This section was measured by Dr. A. Rowe in 1898, and he kindly allows me to publish the results, which are as follow:—

	feet.
Zone of *Terebratulina* - - - - - - - - -	72
,, of *Rhynchonella Cuvieri* - - - - - - - -	56
,, of *Ammonites Mantelli* - - - - - - - -	$5\frac{1}{2}$

Here, therefore, the Middle Chalk is 128 feet thick.

The *Terebratulina* zone can also be examined in the cliffs below Whitlands Coastguard Station, and it forms the highest part of the cliffs south of Rousdon for the distance of nearly a mile. It does not, however, come into the Bindon cliffs nor is it seen again between them and Axmouth.

West of Seaton the whole of the zone is brought in again by the great syncline at Beer; it is visible at the southern end of Whitecliff (see Fig. 77), but is most accessible along the north side of Beer Harbour (see Fig. 78). The section here has been described in detail by Prof. Barrois, and I could recognise his enumeration of beds without difficulty up to his No. 33, but above that we do not agree. The following is an upward continuation of the section given on p. 436.

		feet.
9	White chalk with many black flints and some yellowish lumps (Barrois 21) - - - - - - - - - - -	3
10	Soft chalk without flints (*Ter. gracilis* var. *lata*), passing up into chalk with flints (B. 22, 23) - - - - - -	7
11	Soft chalk with many flints, both scattered and in layers, *Ter. lata* is common (B. 24, 25, 26) - - -	8
12	Nearly continuous layer of black flint (B. 27).	
13	Marly chalk veined with grey, no flints - - - -	3

The succeeding beds are inaccessible, but as judged by the eye are as follows:—

		feet.
14	Chalk with scattered flints (Barrois 28, 29) - - about	15
15	Chalk with two layers of flint nodules (B. 30, 31, 32) ,,	4
16	Chalk without flints, soft and marly in lower part so as to weather into a niche (B. 33) - - - - about	6
17	Chalk with flints, both scattered and in layers ,,	20

Above this is a talus slope which conceals the junction of the *Terebratulina* zone with that of *Holaster planus*. There is probably about 20 feet more of the former zone, making a total of about 93 feet (if Bed 8, p. 436, is included). This upper 20 feet can be seen at the south end of Whitecliff, and in it there is a layer of dark grey marl.

The large quarries (not now worked) north-west of Beer and just north of Court Barn expose a very good section through the zone of *Holaster planus* and a large part of the *Terebratulina* zone. The dip being to the south-east, the highest beds come in at the south-east end, and the descending succession is as follows:—

		feet.
Upper Chalk.	Hard nodular rocky chalk with scattered flints, mostly inaccessible, zone of *M. cortestudinarium* -	10
	Conspicuous course of large black flints.	
	Rough chalk with hard lumps in layers, *Holaster planus* and *Terebratula carnea* - - -	16
	Rough whitish chalk with large flints at intervals	3
	Hard compact chalk with scattered bits of brown phosphate - - - - - - - -	1
Terebratulina Zone.	Solid chalk with scattered flints and a few hard lumps - - - - - - - - - - -	3
	Course of hard yellow nodular chalk, passing down into less nodular chalk with scattered flints and a flint layer at the base - - - - - -	7
	Softer yellowish-white chalk with a few scattered flints, *Inoceramus Cuvieri* - - - - - -	4½
	Laminated marly chalk with a thin seam of dark grey argillaceous marl at the base - - -	½
	Soft marly chalk with a row of large flints in the lower part - - - - - - - - -	1
	Firm chalk with scattered flints of very irregular shape and long projections, *Ter. gracilis* var. *lata*	10
	Rather hard chalk with scattered flints - - -	2
	Soft massive whitish chalk crowded with *Ter. lata*, some scattered flints both large and small - -	6
	Soft white chalk with many scattered flints, especially at top and bottom, *Ter. lata* very common - - - - - - - - - -	6
	Massive bed of firm white chalk without flints, *Ter. lata* and *Ter. striata* - - - - - -	4
	Marly chalk in two layers, weathering into shaly chalk - - - - - - - - - - -	1½
	Harder chalk with yellow stains and two courses of large irregular flints, yellow stained - - -	6
	Softer chalk with scattered flints, having finger-shaped or horn-like projections, *Ter. lata* -	8
		89½

This quarry, therefore, shows about 20 feet belonging to the *Holaster planus* zone and nearly 60 feet of the *Terebratulina* zone. Supplementing the section by the thickness seen in Beer cliff below the niche of marly chalk the total thickness of this zone would be 93 feet.

The lower 40 feet of this zone is exposed in the Beer freestone quarries, and the section has been given on p. 442.

From Beer Harbour to Beer Head there is a fine range of cliffs from 200 to 300 feet in height, but as the beds are nearly horizontal and the cliffs are nearly vertical the *Terebratulina* zone is nowhere accessible. If, however, one lands at the little bay known as Pounds Pool and looks up at the cliff, the observer can easily trace the base of this zone (see p. 437), and between 30 and 40 feet above it he will see a band of flintless chalk with a shaly layer at the base. This band is evidently a continuation of that which occurs about 40 feet up in the zone at Beer. About 24 feet higher still runs a thin layer of dark grey shaly marl like that seen in the quarries north of Beer. These two bands are in fact continuous all the way from Beer to Beer Head.

West of Beer Head in the Hooken landslip, between the path which leads up from Little Beach and that which leads down from the top of the cliff, a fairly continuous section of this zone can be examined. This was measured partly by me and partly by Mr. J. Rhodes, and is as follows:—

		feet.
	Rough yellowish nodular chalk with scattered bits of phosphate; base of *Holaster planus* zone.	
Terebratulina Zone, 105 feet.	Less nodular chalk with flints in layers and scattered, lower part with grey marly streaks, *Micraster corbovis* - - - - - - -	13
	Thin layer of grey shaly marl - - - -	½
	Massive chalk with layers of flints 2 to 4 feet apart, and some scattered flints, *Ter. gracilis* var. *lata* -	26
	Massive greyish-white chalk with few flints, *Ter. gracilis*, var. *lata* - - - - - -	6
	Grey marly chalk, *Ter. gracilis* var. *lata* - -	2
	Chalk without flints, massive, *Ter. gracilis* var. *lata*	3
	Chalk with grey marly streaks and several layers of large flints, *Ter. gracilis* var. *lata* - - -	11
	Chalk with many scattered flints - - - -	21
	Greyish chalk with a marly layer at base - - -	2½
	Chalk with flints in layers and scattered, *Ter. lata* -	20
	Limestone of *Rhynch. Cuvieri* zone (see p. 438).	
		105

Here, therefore, the *Terebratulina* zone is still thicker than at Beer, and it appeared to me that this increase of thickness was chiefly in the lower part of the zone, as if it were complementary to the thinning of the underlying zone of *Rhynchonella Cuvieri*. It will be noticed that the upper layer of grey marl occurs at about the same distance from the summit of the zone, and that the lower layer of marly chalk is at about the same distance below it, but that the latter is much further up from the base of the zone (nearly 58 feet), while a third marly layer comes in about 20 feet from the base.

The lower part of this zone is Mr. Meyer's Bed 18, and his Bed 19, described as "hard chalk without flints," is doubtless the band of nearly flintless chalk which occurs about the middle of the zone. The higher beds were not distinguished by Mr. Meyer, who classed them together as Bed 20, "white chalk with numerous flints."

West of the fine cliff below the Southerndown coastguard station the course of the *Terebratulina* chalk can be followed by the eye in the upper part of the Hooken cliffs, and the base of this zone can be seen to overlap the rough nodular chalk of the underlying *Rhynch. Cuvieri* zone and to rest on a grey bed which looks like sandstone. Then the lowest beds of the *Terebratulina* zone begin to disappear, till a conspicuous bed of flintless chalk, with a visible layer of flints below, comes down to the junction-plane. This is probably the 2½-foot bed of greyish chalk which occurs about 20 feet above the base in the last section. Beyond, the overlying chalk with scattered flints rests on an eroded surface of the basal portion of the fossiliferous Cenomanian grit, as described on p. 137; so that, as compared with the section near the Coastguard House, 80 feet of rock are here missing.

Crossing Branscombe Mouth and walking westward to Berry cliff, over a mile from the Coastguard Station, we find the lower beds of the *Terebratulina* zone come in again (see p. 443), though covered and deeply trenched by hollows filled with gravel and clay with flints. It consists of soft white chalk with frequent flints, both scattered and in layers, but in no place is more than 30 feet exposed. Mr. Rhodes obtained a few fossils.

Beyond this cliff no chalk higher than the zone of *Rhynch. Cuvieri* has been seen.

List of Fossils from the Middle Chalk of Devonshire.

The late Mr. Meyer kindly sent me a revised list of the fossils in his collection, which he obtained from the zone of *Rh. Cuvieri* (his beds 14, 15, 16, 17), with the localities from which they came; to this I have added a few other species found by myself or Mr. Rhodes. Dr. Rowe has kindly sent me lists of the fossils found by him in 1898, and these I have entered separately with the mark "x." The Beer Stone is included in Bed 15.

The localities are indicated thus :—

a. West of the Axe mouth.	c. Beer Head and Hooken.
b. At and near Beer.	d. Branscombe Cliffs.

—	Zone of Rh. Cuvieri.				Zone of Ter. gracilis.	
	Bed 14.	Bed 15.	Bed 16.	Rowe	Beds 17, 18, 19.	Rowe.
Pisces.						
Corax falcatus, *Ag.*	—	—	—	x	—	—
Lamna appendiculata, *Ag.*	—	—	a	x	c	—
Ptychodus mammillaris, *Ag.*	—	b	—	—	—	—
Pycnodus sp. (palatal tooth)	b	—	—	—	—	—
Scapanorhynchus raphiodon, *Ag.*	d	—	—	—	c	x
Cephalopoda and Gasteropoda.						
Ammonites [*Acanth.*] Cunningtoni, *Sharpe*	a	—	—	—	—	—
„ [„] cf. navicularis, *Mant.*	a	—	—	—	—	—
„ [*Prionoc.*] Neptuni, *Gein.*	d	—	—	—	—	—
„ [*Acanth.*] rusticus, *Sow.*	—	—	a	—	—	—
Nautilus sp.	—	b	—	—	—	—
Baculites sp.	—	—	—	—	b	x
Pleurotomaria sp.	—	—	—	x	—	—
Lamellibranchiata.						
Inoceramus Brongniarti? *Sow.*	—	—	c d	—	a d	x
„ Cuvieri, *Sow.*	a	—	d	—	b	x
„ cf. Cripsi, *Mant.*	—	—	c	—	—	—
„ mytiloides, *Sow.*	a b	a b c	a b c d	x	d	x
Lima sp.	—	c	—	—	—	—
Ostrea vesicularis, *Lam.*	a	—	c	x	c	—
Pecten, sp.	—	—	—	x	—	—
„ (Neithea) quinquecostatus, *Sow.*	—	—	—	x	—	—
Plicatula Barroisi, *Peron*	—	—	—	—	—	x
Radiolites, cf. angeoides, *Lam.*	—	—	—	—	c	x ?
Spondylus latus, *Sow.*	—	—	d	—	—	—
„ spinosus, *Sow.*	—	—	d	—	c	x
Teredo amphisbæna, *Goldf.*	a	—	c	—	—	—
Brachiopoda, &c.						
Kingena lima, *Defr.*	—	—	—	—	d	—
Rhynchonella Cuvieri, *d'Orb.*	b c d	a b	a b c d	—	b c	x
„ cf. dimidiata, *Sow.*	b c	—	—	—	—	—
„ plicatilis, *Sow.*	—	—	a b d	—	c	—
„ reedensis, *Eth.*	—	—	—	—	—	x
„ Wiesti, *Dav.*	a	—	—	—	—	—
Terebratula biplicata? *Sow.*	—	a	—	—	—	x
„ cf. arcuata, *Roemer*	c	—	—	—	—	—
„ semiglobosa, *Sow.*	—	a b	b c d	x	c d	x
Terebratulina gracilis, var lata, *Eth.*	—	a	—	—	c	x
„ striata, *Wahl.*	—	—	—	x	c	x
Eschara Acis, *d'Orb.*	—	—	—	—	—	x
„ Lamarcki, *Hag.*	—	—	—	—	—	x
Micropora sp.	—	—	—	—	—	x
Annelida.						
Serpula ampullacea, *Sow.*	—	—	—	—	—	x
„ plexus, *Sow.*	—	—	—	x	—	—
Echinodermata.						
Bourgueticrinus ellipticus, *Mill.*	—	—	—	x	—	x
Cardiaster pygmæus, *Forbes*	b c d	a c	a b c d	x	—	x
„ (allied to rostratus)	c	—	—	—	—	—
Cidaris dissimilis, *Forbes*	—	—	—	—	d	—
„ hirudo, *Sorig.*	b c d	—	d	x	—	—
„ cf. perornata, *Forbes*	—	—	c	—	—	—
„ serrifera, *Forbes*	d	—	—	x	—	x
„ Sorigneti, *Gein.*	d	—	d	x	d	x
Cyphosoma granulosum, *Goldf.*	—	—	b	—	—	—
„ radiatum, *Sorig.*	—	—	—	—	—	x
Discoidea Dixoni, *Forbes*	a b c d	a c	b c d	x	b c	x
„ minima, *Ag.*	b c d	c	—	x	—	x
Echinocyphus difficilis? *Ag.*	—	—	c	—	—	—
Galerites castanea, *Brongn.*	a c d	b c	b c d	x	—	—
„ subrotundus, *Mant.*	b c	?	b c d	x	c d	—
Glyphocyphus radiatus, *Hœn.*	—	—	—	x	—	—
Hemiaster minimus, *Ag.*	a b d	b	c	x	c d	—
Holaster planus, *Mant.*	—	—	—	—	c	—
Metopaster cornutus, *Sladen*	d	—	—	—	—	—
Micraster corbovis, *Forbes*	b	—	—	—	a c	x
„ Leskei, *Desm.*(=breviporus)	—	—	—	x	—	—
Peltastes clathratus?, *Ag.*	—	—	c	—	—	—
Pentacrinus Agassizi, *Hag.*	d	—	d	—	—	—
Pseudodiadema sp.	—	—	—	—	c	—
Salenia granulosa, *Forbes*	—	—	—	x	c	—
Actinozoa.						
Parasmilia centralis, *Mant.*	—	—	—	x	c	x
Spongida.						
Craticularia Fittoni, *Mant.*	—	—	—	—	—	x
Cephalites sp.	—	—	—	x	—	x
Guettardia stellata, *Mich.*	—	—	—	—	—	x
Plocoscyphia convoluta, *Smith*	—	—	—	x	—	—
Porosphæra globularis, *Phil.*	—	—	—	x	—	x
Ventriculites decurrens, *Smith*	—	—	—	—	—	x

CHAPTER XXXV.

THE MIDDLE CHALK IN WILTSHIRE.

General Description.

The course of the Middle Chalk through Wiltshire is very irregular, because of the anticlinal flexures which bring up the underlying beds in the Vales of Broad Chalk, Wardour, Warminster and Pewsey, so that the boundary lines run for long distances in an east to west direction. The width of surface occupied by the Middle Chalk in this county also varies greatly, for where the dip is slight it runs far up the numerous valleys which cut through the chalk hills, while where the dip is high the space so occupied is but a narrow strip of ground.

From above Charlton near Shaftesbury the outcrop runs eastward and surrounds the several irregular inliers of Lower Chalk which occur in the Vale of Broad Chalk. This vale is separated from that of Wardour by a long and narrow ridge of chalk, the upper part of which is capped by the beds which overlie the Chalk Rock. This ridge terminates westward in the promontory which is called White Sheet Hill, and the northern slope of the ridge forms a fine escarpment ending eastward in a great curve which is known as Hoop Side (see Map in Vol. I., Plate opp. p. 248).

On the north side of the Vale of Wardour the outcrop is very narrow, owing to the high dips, and in several places it is cut out altogether by the fault which runs along this tract. From Mere it passes northward to the valley of the Deverill and up on to Brimsdown Hill, near Maiden Bradley; thence eastward to the valley of the Wily, along which it is exposed as far as Stapleford. It forms the upper slopes of the hills east of Heytesbury and Warminster, and an outlying patch of it forms Cley Hill, three miles west of Warminster.

From Westbury, north of Warminster, the main outcrop of the Middle Chalk runs eastward along the escarpment to Lavington and thence still eastward along the southern side of the Vale of Pewsey. There are, however, numerous inliers in the deep valleys which trench the chalk of Salisbury Plain south of the main escarpment, and inlets from the outer tract run southward up the valley which breaches the escarpment ridge at Lavington and also down the valleys of the Avon and the Collingbourn.

At the eastern end of the Vale of Pewsey the outcrop of the Middle Chalk opens through a gap in the watershed ridge, and thus becomes continuous with the cincture of Middle Chalk that surrounds the

Shalbourn inlier. From the gap above mentioned, near the village of Marten, the basset surface runs westward in a narrow band along the north border of the Vale of Pewsey as far as Arn Hill. Near that spot the northerly dip becomes less steep, and this division occupies more space, partly in the form of three outlying tracts.

North of the valley of the Kennett it spreads out over the broad area of the Marlborough Downs, but is covered here and there by outliers of Upper Chalk and of clay with flints. From Ogbourne St. George it occupies an irregular space around the inliers and inlets of Lower Chalk near Liddington Warren, Wanborough Plain, and Bishopstone Down.

The component parts of the Middle Chalk in Wiltshire are similar to those of the same stage in the adjoining counties of Dorset and Hampshire. The Melbourn Rock has its usual character of a hard, nodular, chalky limestone from 5 to 10 feet thick, and its outcrop generally forms a feature which can be easily traced across the country. This is succeeded by less hard nodular chalk passing up into firm-bedded chalk, and the higher beds (*Terebratulina* zone) consist of massive white chalk, firm rather than soft, in the upper part of which there are generally two or three layers of black flints.

The thickness of the Middle Chalk appears to increase both northwards and eastwards. A boring at Lower Pertwood Farm, near Monkton Deverill, between the Vales of Wardour and Warminster, proved it to be there only 80 feet thick, and this seems to be its thickness along the northern border of the Vale of Wardour. At Warminster and Westbury it is about 90 feet, but eastward along the southern border of the Vale of Pewsey it thickens till at the eastern end it is from 140 to 150 feet. North of Devizes it thickens in the same way from 100 to about 140 feet west of Swindon.

Fossils are not abundant in the Middle Chalk of Wilts, and very few were found either by Mr. Bennett or myself during our mapping of the areas described, but it is probable that most of the usual species would be obtained from some of the quarries if the workmen were employed to look for them. The most notable exposures will now be mentioned, commencing in the most southern part of the county.

STRATIGRAPHICAL DETAILS.

In the Vale of Broad Chalk, many exposures of Middle Chalk can be found, but, according to my colleague, Mr. F. J. Bennett, there are few large quarries in it. He saw the Melbourn Rock at Broad Chalk at the top of a quarry north of Chalk-pit House, and again in the road south of Knighton.

I visited Homington and Combe Bisset in 1890 ; south of Homington I found a quarry in the zone of *Rh. Cuvieri* showing :

	feet.
Hard chalk, broken and weathered, with two layers of greenish marl. *Inoc. mytiloides* - - - - - - -	6
Hard whitish nodular limestone - - - - seen for	6

In the lane leading out of the road from Homington to Combe the top of the Lower Chalk (with the Belemnite marl) and the overlying Melbourn Rock are well seen. At Combe Bisset there is a large pit in the lower part of the Middle Chalk about 40 feet deep; the chalk at the bottom is hard and contains *Inoceramus mytiloides;* higher up it is tough and massive with several layers of soft marl, and near the top there are many grey flints. The beds are dipping to the north at about 4 deg.

There are no good quarry sections in this division along the south side of the Vale of Wardour, but the whole of the Middle Chalk can be traced in the roadway ascending Compton Down; first, the rough nodular chalk of the *Rhynchonella Cuvieri* zone, then the firm white chalk of the *Terebratulina* zone overlain by the hard rocky beds of the Chalk Rock.

Along the northern border of the Vale of Wardour there are a few places where the zone of *Rhync. Cuvieri* can be seen in spite of the high dips.

A quarry north-east of Baverstock shows about 25 feet of this zone, hard, rough and nodular in the lower part, which cannot be far from the Melbourn Rock. The two common fossils were found in the upper beds, and the dip is about 33 deg. to the north-east.

The Melbourn Rock, passing up into hardish bedded chalk containing *Rhynchonella Cuvieri* and *Inoceramus mytiloides,* is also exposed in a small pit three-quarters of a mile north-east of Dinton. The dip here is about 20 deg. north, and an old excavation close by, which must have shown the *Terebratulina* zone at the Chalk Rock, is still exposed at the northern end, dipping at 45 deg.

A quarry half a mile north of the village of Ridge shows the following section, the beds dipping at about 15 deg. to the north:—

	feet.
Hard bedded whitish chalk - - - - - - - -	15
Hard yellowish nodular chalk in regular beds, with several layers of marl - - - - - - - - - - -	10
Marked layer of marly chalk	
Hard nodular yellowish chalk (Melbourn Rock) - - -	5
Greenish grey marl and marly chalk - - - - - -	6
Talus concealing lower beds.	

The Melbourn Rock is exposed behind the lime-kiln of the quarry on the road from East Knoyle to Hindon, and in the quarry itself there is at the base 2 feet of hard cream-coloured chalk, overlain by a seam of greenish marl; and then about 50 feet of firm white chalk in thick beds, succeeded by Chalk Rock and Upper Chalk. The total thickness of Middle Chalk here can hardly be more than 80 feet.

The whole of the Middle Chalk, with a total thickness of only 79½ feet, was traversed in a boring at Lower Pertwood, a farm 1¾ mile east of Monkton Deverill; the boring was made by Mr. H. J. G. Hole, of Poyntington, Sherborne, to whom I am indebted for the particulars given below and for samples which enabled me to identify the Chalk Rock and the Melbourn Rock :—

		feet.
Upper Chalk.	Soft but lumpy chalk with a few scattered flints	48
	Chalk lumps in soft chalk with some layers of flints	36
	Beds of solid chalk - - - - - - -	12
	Chalk Rock—Hard rocky chalk in three beds -	8
Middle Chalk.	Solid soft chalk with flints at two levels - -	42
	Solid chalk without flints, harder below - -	29
	Hard chalk, partly very hard (Melbourn Rock) -	8½
Lower Chalk.	Firm chalk - - - - - - - - - -	19
	Marly chalk with plenty of water near bottom -	82

Mr. J. Scanes, of Maiden Bradley, informs me that between that place and Mere the thickness of the Middle Chalk appears to be less than 60 feet, so far as can be judged from the levels at which the two rock-beds crop out on the hill-slopes.

The hills east of Warminster, which are crowned by Battlesbury and Scratchbury Camps, and Cotley Hill near Heytesbury, are all outliers of Middle Chalk ; the Melbourn Rock is exposed in a small pit to the south of Scratchbury Hill. The main outcrop passes behind these hills, and the outcrop of the Melbourn Rock has been traced in and out of the numerous combes and valleys which trench the great plateau of the Chalk.

From near Heytesbury this rock has been mapped along each side of the valley of the Wily as far as the village of Wily and the hamlet of Deptford, where it passes beneath the river-alluvium.

Mr. F. J. Bennett informs me that the rock is seldom well exposed in the Wily Valley, but he saw exposures of it in an old lane south of Boyton, and again south of Sherrington in an old trackway leading eastward. Hard-bedded chalk which probably belongs to the zone of *Rhynchonella Cuvieri* is to be seen in the road cutting at Deptford and in a chalk-pit by Deptford Field Barn.

A good section of nearly the whole of the Middle Chalk is exposed in the large quarries on Arn Hill, north-east of Warminster. This section, measured in 1899, was as follows :—

		feet.
Zone of *Hol. planus.*	Lumpy or nodular white chalk, inaccessible, but having a clearly-marked base line - about	15
	Chalk rock with three layers of green-coated nodules and some scattered flints, passing down into hard nodular white chalk - - - -	3½
Zone of *Terebratulina.*	Clean white chalk, in thick beds - - about	12
	White chalk between two lines of flint nodules -	1½
	Firm white chalk in beds 2 or 3 feet thick, with marly partings ; a few scattered flints in the upper part - - - - - - - about	35
Zone of *Rhynch. Cuvieri.*	Firm white chalk, becoming harder below, and passing into hard chalk with much Inoceramus shell - - - - - - - about	30
	Very hard white nodular chalk (top of the Melbourn Rock) - - seen for	1
	About	98

There is probably another 8 or 9 feet of Melbourn Rock below the quarry floor, and the total thickness of the Middle Chalk here will therefore be about 88 feet. The beds dip at 3 or 4 deg. to the north. Prof. Barrois gave an account of this section in 1876,* but the thicknesses he assigns to the several beds are all too great. He records the following fossils from the *Terebratulina* zone :—

Inoceramus mytiloides.
„ Brongniarti.
Pinna decussata.
Rhynchonella Cuvieri.
Terebratulina gracilis.

The large quarry on Cley Hill, west of Warminster, shows a similar section, but exposes more of the Melbourn Rock at the base, and the total thickness appears to be rather less. Mr. Scanes has recently made a careful measurement and found it to be about 78 feet.

The only good exposure of the Middle Chalk near Westbury is in the large quarry on the Long River Road. The weathered face near the road shows about 8 feet of yellowish-white chalk, hard nodular beds alternating with soft marly layers containing loose nodules; *Inoceramus mytiloides* and *Rhynchonella Cuvieri* are abundant. I was informed by workmen that the pit was formerly worked down to a very hard rock, and that the lowest layers came out in large blocks weighing over a ton in weight. This was evidently the Melbourn Rock, but is not now visible.

On the inner face of the quarry the beds are more massive and less weathered; the lower part is hard and contains some *Inocerami*, but the higher beds belonging to the *Terebratulina* zone are difficult to reach. The height of this inner face must be nearly 70 feet above the floor of the quarry. The total thickness of Middle Chalk here must be from 90 to 100 feet, as the outcrop of the Chalk Rock is some distance above the top of the quarry.

The outcrop of the Melbourn Rock can be seen in most of the roadways which ascend the escarpment near Market Lavington and Urchfont, but there are no good exposures of the overlying beds along this tract. Some 20 feet of the *Terebratulina* zone are, however, exposed below the Chalk Rock in a quarry on Redhorn Hill, south-east of Urchfont.

Mr. Bennett found an exposure of the *Rhynchonella Cuvieri* zone in a pit about two miles south of Marden Church, showing:—

	feet.
Rather soft white chalk - - - - - - -	1
Hard nodular chalk - - - - - - - - - -	5
Smooth chalk, passing down into greyish laminated marl -	$\frac{3}{4}$
Hard smooth chalk - - - - - - - - - - -	1
Hard nodular chalk in two beds, separated by a thin seam of marl - - - - - - - - - - -	2

From these beds he obtained *Inoceramus mytiloides, Rhynchonella Cuvieri,* and *Discoidea Dixoni.*

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* Recherches sur le Terrain Crét. Sup. p. 58.

The hard nodular chalk of the Melbourn Rock can be seen in the roadway ascending Cleeve Hill, south of Charlton, and the *Terebratulina* zone was observed by Prof. Barrois in several quarries north of Enford which expose the usual massive white chalk, with thin layers of marl, and he obtained *Galerites subrotundus* and *Inoceramus Brongniarti.* (Recherches, p. 53.)

A good section of the Melbourn Rock is exposed in a quarry half-a-mile north-east of Wooton Rivers, south of Marlborough, and I am indebted to Mr. F. J. Bennett for the following account of it:—

	feet.
Hard cream-coloured nodular chalk, one bed near the base being specially hard and nodular (*Melbourn Rock*), about -	12
Soft yellowish marl - - - - - - - - - - -	½
Hard nodular chalk - - - - - - - - - - -	1
Greyish chalk touched below.	

The beds have a dip of 28° to the north. The yellowish marl and hard chalk below it may also be part of the Melbourn Rock.

North of Devizes, the central part of the *Rhynch. Cuvieri* zone is quarried on Windmill Knowl, the pit being about 20 feet deep, showing thick beds of hard whitish chalk with seams and streaks of greenish grey marl; *Inoceramus mytiloides* is the prevalent fossil. The weathered top of the Melbourn Rock is exposed in shallow pits on the north side of the plantation on Roundway Hill, and its outcrop can be traced all round the top of King's Play Hill, as well as round the larger outliers which rise into Morgan's Hill and Oldbury Castle south and east of Calstone.

The *Terebratulina* zone is quarried on the western slope of Oldbury Hill, the pit exposing about 20 feet of massive white chalk, which is carted down to Calstone for the manufacture of whiting.

My colleague, Mr. F. J. Bennett, informs me that, notwithstanding the extent of ground covered by this zone in the country to the east and west of the Marlborough Downs, the beds are only seen here and there, and no very good sections are exposed.

Along the line of the Swindon and Marlborough railway the Melbourn Rock appears to be faulted down against Lower Chalk near Whitefield Farm, so that its outcrop is not traversed by the railway. In the cutting north of Ogbourne Station Mr. Bennett found hard chalk at the northern end overlain southward by 15 feet of firm white chalk, somewhat weathered and rubbly. This probably belongs to the upper part of the *Rh. Cuvieri* zone.

CHAPTER XXXVI.

THE MIDDLE CHALK IN BERKSHIRE, OXFORDSHIRE, AND BUCKINGHAMSHIRE.

1. Berkshire.

From Wiltshire the basset surface of the Middle Chalk passes into Berkshire, and at first it occupies an area of considerable width south of Ashbury, Woolston, and Kingston Lisle. Along this tract it forms the summit of the chalk escarpment, and extends southward down the valleys which open into that of the Lambourn river to and beyond the town of Lambourn.

From Sparsholt Down eastward the summit ridge is formed of Upper Chalk resting on the Chalk Rock, while the outcrop of the Middle Chalk is restricted to the slope of the escarpment and to a couple of narrow inliers, one south of Childrey Warren, and the other at the head of the Ilsley Valley.

South-east of Chilton the escarpment is traversed by the valley of an old river-course, and the area occupied by the Middle Chalk here widens out again and forms the triangular plateau marked on the older Ordnance map as Blewberry Plain. Thence it passes round Blewberry Hill and trends south-eastward into the valley of the Thames, but running up into the long combes which open eastward toward Moulsford and Streatley.

The two zones of the Middle Chalk in Berkshire have a combined thickness of about 150 feet, of which the lower 50 or 60 feet may be referred to the *Rhynchonella Cuvieri* zone.

Stratigraphical Details.

The chalk of the *Terebratulina* zone is exposed in the pathway west of the "Horse" on Whitehorse Hill, and consists of firm white chalk with a few small finger-shaped flints. Lower down there is hard chalk with much *Inoceramus*-shell, but its base is obscured. The Melbourn Rock, however, is exposed in the upper pit on Blowing stone Hill, which shows—

	feet.
Hard nodular chalk - - - - - - - - - -	10
Very hard nodular rock, mottled with greenish-grey, seen for	4

There is a marked plane of division at the top of this massive rock-bed, but, though the Lower Chalk was exposed at the entrance to the quarry, the thickness of the rock could not be ascertained.

The hard nodular chalk of the *Rh. Cuvieri* zone can again be seen in two pits near Childrey Lodge, and the passage from this zone to that above is exposed in a pit where the roads branch south of Letcombe Basset.

South of Wantage the hard chalk of the *Rh, Cuvieri* zone forms the promontory on which the workhouse stands, and there is a pit in the *Terebratulina* zone south of the workhouse.

The Melbourn Rock is well exposed at the top of the quarry south of Chalkhill Barn, two miles south-east of Wantage, where the beds visible in 1887 were—

		feet.
Soil and rubble of hard chalk		4
Melbourn Rock.	Hard compact bedded nodular rock	5
	Very hard rough nodular rock	3
Lower Chalk.	Marls and chalk (see p. 171)	22

The middle part of the *Rh, Cuvieri* zone, full of *Inoceramus mytiloides*, is quarried a little higher, by the side of Goddard's Road.

The Melbourn Rock can be seen in the railway cutting south-east of Chilton, near Downs Barn, and passes up into hard nodular chalk which includes a layer of hard yellow rocky chalk.

A fairly good section of the beds above the Melbourn Rock is exposed in a quarry on the hill south of Upton. The beds dip at 3° or 4° to the S.S.W., and about 30 feet must be seen. The highest part is firm and fairly compact, becoming yellowish and nodular below, and passing down into hard nodular chalk which is part of the Melbourn Rock; the base of this is not seen, but the lowest bed is very hard, rough, and mottled with greenish marl. In the higher beds *Inoceramus mytiloides* is abundant, with *Rhynchonella Cuvieri* and *Terebratula semiglobosa.*

Along Whiteshoot Road, leading from Blewbury to Woodway Farm, portions of the *Terebratulina* zone are exposed in a succession of small excavations made to carry off the rainwater; they show firm white homogeneous chalk with thin seams of greyish marl, but near the farmstead the chalk becomes harder and weathers out into hard rough lumps.

Kingstanding Hill, west of Moulsford, is part of a long spur of Middle Chalk. The *Terebratulina* zone is exposed by the roadside about 50 feet below the outcrop of the Chalk Rock, and I found *Terebratulina gracilis* var. *lata* and *Discoidea minima* in soft white chalk. Down the slope of the hill, on the road to Streatley, the harder chalk of the *Rhynch. Cuvieri* zone can be seen with the outcrop of the Melbourn Rock.

South of Moulsford, in the valley of the Thames, the nodular chalk of the *Rh. Cuvieri* zone forms a well-marked ridge and seems to be faulted against the Lower Chalk, for it runs in a nearly straight line between the two main roads striking a little north of east. An old quarry about half a mile south of Moulsford exposes hard yellowish lumpy chalk, which is probably not far above the Melbourn Rock, but is much weathered and disintegrated. No fossils were found.

A quarry just north of Streatley shows about 30 feet of the *Terebratulina* zone, the chalk being firm and white with a few scattered flints in the highest part; from this pit Prof. Barrois obtained *Ostrea vesicularis*, *Spondylus spinosus*, and fragments of *Inoceramus*.

2. OXFORD AND BUCKS.

It will be convenient to describe the Middle Chalk of these two counties together, because this division crosses their narrowest parts where they have a combined width of only about 26 miles, and because certain inlying tracts include parts of both counties.

The general succession and aspect of the beds is similar to those of the Middle Chalk in Berkshire. The Melbourn Rock rises from the alluvium of the Thames near Cleeve Mill, north of Goring. Thence it passes north-eastward and forms a conspicuous feature or ridge in advance of the main escarpment as far as Watlington and Lewknor. Beyond that place its outcrop retreats to the foot of the main escarpment. The Chalk Rock and its associated beds rise from the Thames near Whitchurch and mount to higher and higher levels as they pass north-eastward till they reach a height of between 700 and 800 feet.

The chalk which lies between these two bands of hard rocky chalk occupies an area of some width between Ipsden and Watlington, but the tract then becomes much narrower until it reaches the valley of the Loudwater.

In Buckinghamshire the escarpment of the Chalk is breached by the heads of several valleys that drain south-eastward into the Thames, and along these valleys the Middle Chalk is exposed for long distances. Thus, in the valley of the Loudwater, Middle Chalk is exposed along its whole length from near Risborough to its junction with the valley of the Thames.

Flints occur throughout the *Terebratulina* zone, chiefly along a few definite places which are some distance apart vertically, and they are only sparsely distributed along these planes.

It is rather remarkable that in passing across the valley of the Thames the Middle Chalk shows a sudden and considerable increase of thickness. In Berkshire, west of Moulsford, the thickness cannot be more than 160 feet, while on the Oxford side, near Ipsden, it is at least 200 feet; of this about 60 feet may be assigned to the zone of *Rh. Cuvieri* and about 140 feet to the *Terebratulina* chalk.

In Buckinghamshire its total thickness appears to be from 200 to 220 feet, and it is apparently the upper zone which thus increases in thickness. As stated on p. 362, we now include in this zone those beds below the Chalk Rock which were referred to the zone of *Holaster planus* in the Memoir on the Geology of

London (1889, p. 66). These consist of solid and massive chalk, which near the top passes up into harder and rougher nodular chalk.

STRATIGRAPHICAL DETAILS.

Zone of Rhynchonella Cuvieri.

Part of this zone is exposed in an old pit about 30 feet deep by the side of the Thames at Goring, but is much weathered. The looser parts are decomposed into rubbly yellowish chalk, while lenticular masses of hard, shelly chalk project from the face of the pit. *Rhynchonella Cuvieri* and *Inoceramus mytiloides* are common; *Cidaris dissimilis* (a test), *Galerites subrotundus*, and *Terebratulina gracilis* var. *lata* were also found. Similar chalk, but in more massive beds, very hard and resembling the top of the Melbourn Rock, occur at the level of the water near Cleeve Mill.

At the north end of the Temple grounds, where one would expect to find still lower beds, there is a quarry which appears to show the junction of this zone with that of *Terebratulina*, viz. :—

	feet.
Soil and rubble	2–4
Soft white chalk with finger-like flints	8
Hard rocky yellowish chalk with *Inoceramus mytiloides*	10–14
About	24

Between this and Watlington there are no good sections, but a quarry east of Watlington Farm shows the greater part of the zone; its upper level being from 25 to 30 feet deep in hard whitish chalk without flints, but yielding *Galerites subrotundus*; the lower level shows 24 feet of hard yellowish-white chalk with bands of loose nodular chalk. *Inoceramus mytiloides* and *Rhynchonella Cuvieri* are abundant, except near the bottom, where the chalk is very hard and is approaching the Melbourn Rock.

Another good section at about the same horizon, but showing rather an unusual succession of beds, is exposed in a quarry opened in a field three-quarters of a mile east of Shirburn, the section seen in 1886 being :—

	feet.
Hard nodular rocky chalk without distinct bedding, weathering into irregular lumps	14
Hard compact rock, breaking into large blocks	4
Hard rocky chalk in one bed, but having a central nodular or concretionary band	1½
Compact chalk in thin beds, smooth and brittle, with marly partings	3
Grey marl containing lumps of hard white chalk, large and small, some green-coated	½
Hard compact chalk in thick massive beds; may be top of Melbourn Rock - seen for	4
	27

The Melbourn Rock can be seen overlying the Belemnite Marl in the road cutting half a mile south-east of Crowell.

Passing into Buckinghamshire, the base of the Melbourn Rock is exposed in a small pit by the farm called Brimmers, south of Princes Risborough, about 6 feet of hard rough nodular rock being seen in 1885.

A complete exposure of the Melbourn Rock is shown in the quarry near Butler's Cross or Chalkshire. The details of the Lower Chalk here have been given on p. 179; those of the Middle Chalk are as follows:—

		feet
	Soil and thin-bedded chalk, with a few nodules	2
Melbourn Rock	Marly chalk with loose nodules and a layer of hard white compact rock	1½
	Hard rough yellowish nodular rock in two beds, with a layer of greenish-grey marly chalk between	3¼
	Laminated marly chalk	¼
	Hard whitish rock, with many layers of small nodules, in three beds	5
	Lower Chalk	24

The upper part of the *Rhync. Cuvieri* zone is exposed in the quarries at the east end of Bacombe Hill, west of Wendover; it is hard, cream-coloured, and lies in fairly regular beds. The lower beds and the Melbourn Rock can be seen in the road-cutting nearer Wendover.

Between Wendover and Tring these beds are seen in a quarry on White Hill, a mile north-east of Halton; the lowest consist of hard nodular yellowish chalk with partings of shaly marl and contain *Rhynchonella Cuvieri* above are thick beds of hard heavy chalk crowded in some places with fragments of *Inoceramus mytiloides.* *Galerites subrotundus* also occurs. These beds pass up into the chalk of the overlying zone.

The Melbourn Rock is clearly exposed in a quarry by the side of the main road east of Buckland Wharf, the succession seen in 1884 being:—

		feet.
	Rubbly chalk, passing down into hard yellowish nodular chalk with *Rhynch. Cuvieri*	8
Melbourn Rock.	Hard and massive yellowish rock, rough and nodular on a weathered face	4
	Thin parting of grey marl.	
	Hard yellowish rock enclosing several layers of small nodules	4
Lower Chalk.	Belemnite Marls (see p. 181).	3
	White blocky chalk	10

Terebratulina Zone.

The best exposure of the *Terebratulina* zone in Oxfordshire is a quarry near Potter's Farm, nearly three miles east of Wallingford. The lower level shows about 15 feet of soft white blocky chalk, with a few large scattered flints; about 3 feet from the top is an irregular layer of grey laminated marly chalk. The upper level was disused and talused in 1886. The chalk is burnt for lime.

The highest beds of the zone are exposed in Garson's Lane, about a mile E.S.E. of Ipsden House, and not far below the outcrop of the Chalk Rock. They consist of tough white chalk in solid beds, with a band of soft chalk containing many shells of an *Inoceramus* (probably young *I. Cuvieri*).

There is a pit in the middle or higher part of this chalk in the combe north of Watlington Hill, and another below Bald Hill south-east of Lewknor: both show firm white blocky chalk without flints. Similar chalk has been quarried by the road north-east of Kingston Grove and by the side of the London road up Aston Hill; these pits have yielded *Spondylus spinosus*, *Inoceramus Cuvieri*, *Terebratula semiglobosa*, and *Ventriculites mammillaris*.

There are few good exposures of this zone in Bucks. The beds which form a passage between the two zones are exposed in the upper level of the quarry on White Hill, near Halton (see p. 460). They consist of rather soft but firm white chalk containing *Galerites subrotundus* and large *Terebratula semiglobosa*. About twenty feet are seen, and flints occur rarely; only one small oval one was exposed at the time of my visit.

There are two small exposures near Tring, one about half a mile south-east of Tring, and another in the higher part of the zone south-east of Aldbury.

The highest beds of the *Terebratulina* zone can be seen at several places in Oxfordshire and Buckinghamshire where the Chalk Rock is exposed. Thus a few feet of it are seen in the quarry on Risborough Hill, and some 10 or 12 feet of smooth blocky white chalk are exposed in a smaller quarry at a little lower level. At Great Missenden nearly 30 feet of this zone are visible below the Chalk Rock, the section being:—

	feet.
Chalk Rock Beds (for details see Volume III.) - - -	11
White chalk in thick beds - - - - - - - -	7
Soft chalk lying between two thin layers of marl - - -	2
Soft white chalk in thick beds, with a marly layer at the bottom - - - - - - - - - -	20

The two thin seams of marl are seen again in the same position in a pit east of Havenfield Lodge, north of Missenden, and again in a lane leading from Wendover Dean to Bowood.

There are also some good exposures in the inlying tract of Middle Chalk near Henley. About 40 feet of solid white chalk in thick beds are shown in a large quarry west of Medmenham overlain by Chalk Rock. It is also well shown and easily accessible in a quarry north of Greenland Lodge on the road to Henley; here at least 30 feet are seen of similar massive chalk without flints, but including a thin layer of soft marl about 5 feet below the Chalk Rock. Mr. Hill, when at the Medmenham quarry in 1899, found that this massive chalk was being quarried for building material.

CHAPTER XXXVII.

THE MIDDLE CHALK IN BEDFORDSHIRE AND HERTFORDSHIRE.

General Description.

The tract described in this chapter extends from Tring and Berkhampstead on the west to the country south of Royston on the east, a distance of about 30 miles. It includes a small portion of Bucks, for between Tring and Dunstable the boundaries of the three counties are very irregular.

The Melbourn Rock forms a conspicuous and continuous feature all along this tract, but the width of ground occupied by the overlying beds varies very considerably. Between Tring and Hitchin the escarpment is deeply trenched by the heads of several valleys which drain to the south-east, so that the higher part of the escarpment is divided into a succession of bold hill ranges separated by broad and deep depressions. The upper beds of the Middle Chalk (those which underlie the Chalk Rock) pass into these valleys, and run down them for long distances, because the general inclination of the strata is very little greater than the slope of the valley floors.

Thus in the valley of the Bulbourne the Middle Chalk runs down as far as Box Moor; in the valley of the Gade it runs to Hemel Hempstead.

From above Dunstable it passes into the valley of the Ver, and extends to near Redbourn.

Through these counties the Middle Chalk occupies a considerable width of ground, not because it is any thicker than in Buckinghamshire, but because the escarpment of the Chalk divides itself into two portions, a lower slope crowned by the Melbourn Rock and an upper slope crowned by the Chalk Rock and a variable thickness of Upper Chalk. Between these slopes there is generally a plateau formed by the chalk of the *Rhynchonella Cuvieri* zone and the lower part of the *Terebratulina* zone.

The estimated thicknesses of the zones are as follows:—

		feet.
Zone of *Terebratulina gracilis*, var. *lata*	- about	160
Zone of *Rhynchonella Cuvieri* (including the Melbourn Rock)	- - - - - - - - - -	60
	Up to -	220

STRATIGRAPHICAL DETAILS.

Zone of Rhynchonella Cuvieri.

Tring stands upon the chalk of this zone, but no good exposure of it was seen near this town. About two miles to the north-east, however, by the house called "The Folly," a quarry shows its upper beds; the highest bed is white and contains a layer of black flints, the next 9 feet consist of massive, slightly yellowish or cream-coloured chalk with many fragments of *Inoceramus*, while the lower 6 feet are beds of hard nodular chalk full of *Inoceramus mytiloides* and *Rhynchonella Cuvieri*.

The lower part of the zone is exposed in a pit south of Ivinghoe and east of Pitstone. (See Fig. 43.) The section here in 1884 was:

		ft.	in.
	Hard yellowish nodular chalk, with *Inoceramus mytiloides* and *Rhynchonella Cuvieri* - - - - - - -	6	0
Melbourn Rock.	Very hard nodular rocky chalk, full of small nodules, in several beds - - - -	6	0
	Very hard yellowish nodular chalk - -	3	0
Lower Chalk.	Layer of buff-coloured marl - - - -	0	6
	Hard whitish chalk, passing into next - -	2	0
	Greenish shaly marl, with *Act. plenus* - -	0	2–4
	Softer dull white chalk, up to - - -	8	0
	About	26	0

The beds are dipping at an angle of about 3° to the south east.

The Melbourn Rock is also exposed in a pit three-quarters of a mile south-west of Eddlesborough church, and in another pit by the side of the road to Dagnal, one and a quarter mile south-east of Eddlesborough.

The hard chalk of this zone forms the base of the plateau of Maiden Bower, west of Dunstable, and there are three small outliers of Melbourn Rock between it and the great tumulus of Totternhoe; there are no open sections at present, but the large quarries at Totternhoe may be eventually cut back into the base of the Rock.

The next good exposure of this rock is in the quarry by the side of the railway near Leagrave, north-west of Luton. This quarry has been mentioned on p. 191; the lowest bed of the Melbourn Rock is a massive bed 3 feet thick of very hard nodular chalk and the next 5 feet are nearly as hard, but form thinner beds with marly partings. The rock is nearly white when quarried, but weathers to a creamy yellow tint.

West of Streatley the Melbourn Rock and *Rh. Cuvieri* chalk form a fine and bold piece of country, running out into many promontories which are separated by deep and picturesque combes and valleys. It is evident that the hard rocky chalk has protected the softer lower chalk but has been itself trenched by the action of rain-streams flowing off the higher slopes of the escarpment. The rock is exposed in a pit three-quarters of a mile south-west of Porton, about 7 feet of hard nodular chalk being seen with a marked plane of division at the top, above which are several feet of shelly chalk with fewer nodules.

The best exposure of the *Rhynchonella Cuvieri* zone in this district is in the cutting and quarries by the side of the line south of Hitchin Station. The quarries are carried down below the level of the line, and are sometimes worked down to the bottom of the Melbourn Rock. The succession is as follows:—

	feet.
Soil and chalk rubble - - - - - - - - - -	4
Firm white chalk with *Galerites subrotundus*, and a layer of flints at base - - - - - - - - - - -	6
Firm whitish chalk with much *Inoceramus* shell, *Galerites subrotundus* and *Rhynch. Cuvieri* - - - - -	14
Harder white chalk with *Rhynch. Cuvieri, Inoceramus mytiloides*, and *Terebratula semiglobosa* - - - - -	10
Hard white nodular chalk with the same fossils, and also *Discoidea minima* and *Cardiaster pygmæus* - -	10
Very hard nodular yellowish rock with *Rhynchonella Cuvieri*, top of Melbourn Rock - - - - - - - -	4

Below this there is said to be hard, nodular, greenish-grey rock about 6 feet thick, making the whole about 50 feet thick, but as the highest bed is rather soft homogeneous chalk, and neither *Rhynchonellæ* nor *Inocerami* are common in it, the layer of flints may be regarded as the top of this zone.

The lower part of the zone is again seen in the large quarry at Ashwell, and the beds exposed are:—

		feet.
Middle Chalk.	Hard but brittle yellowish chalk, with many *Rhynch. Cuvieri* and *Inoc. mytiloides* - - - -	10
	Brittle homogeneous chalk (4 in.) breaking vertically into oblong blocks, resting on soft shaly chalk -	2
	Hard chalk with nodules, weathering into layers -	$3\frac{1}{2}$
	Softer yellowish shaly chalk, breaking into lenticular lumps, some nodules - - - - - -	2
	Hard rocky chalk, weathering yellowish, with a rough nodular surface - - - - - - -	$3\frac{1}{2}$
Lower Chalk.	Soft greenish-grey chalk - - - - - -	2
	Hard white chalk - - - - - - - -	1
	Greenish-grey shaly chalk - - - - - -	1
	Blocky whitish chalk - - - - - - -	30

The three lowest of these beds represent the Melbourn Rock, but the shaly chalk in the middle is very unusual at this horizon.

Terebratulina Zone.

The highest beds of this zone are exposed in the quarry by the Chiltern Waterworks, two miles south-west of Tring, the section as seen in 1884 being:—

	feet.
Chalk rock (seen in one corner) - - - - - -	8
Hard white nodular chalk - - - - - - -	8
Thin layer of marl.	
Firm even white chalk - - - - - - - -	11
Thin layer of marl.	
Firm white chalk, massive - - - - - - -	8

Part of this zone is exposed in the quarries at Coldharbour, near Dunstable. The upper level of the chief quarry shows about 30 feet of massive white chalk with a layer of buff-coloured shaly marl. The apparent bedding is really curvilinear jointing, for the planes curve and run into one another. There are no flints, and the chalk is used in the manufacture of whiting. Fossils are rare.

Another good section occurs at the Lime and Whiting Works, half-a-mile north-east of Luton Station. There are three levels to the quarry and they give a combined section through about 60 feet of chalk, the whole being rather soft homogeneous white chalk with a few scattered flints and two layers of grey marl in the central part. *Galerites subrotundus* is common; *Inoceramus Cuvieri, Spondylus spinosus,* and *Terebratula semiglobosa* also occur.

The chalk of this zone occupies a large area near Hitchin, and a good section of its lower beds are exposed in Mr. Ransome's quarry near the railway station, which is a continuation of the section given on p. 464 ; above the beds there noted there is about 70 feet of soft white chalk with a few scattered flints, but no regular layer of flints, except that near the top of the underlying zone. *Galerites subrotundus* and large *Terebratula semiglobosa* are common, with *Terebratulina gracilis* var. *lata, Ptychodus decurrens* and other fossils. Another pit in the fields further south shows rather higher beds of soft chalk containing *Spondylus spinosus,* which does not seem to occur in Mr. Ransome's quarry.

A quarry a quarter of a mile south of Little Wymondley shows 15 feet of soft white chalk, with a band of grey marl and a layer of flints above it ; *Spondylus spinosus*, *Inoceramus Cuvieri ?* and *Terebratula semiglobosa* occur here.

The lower beds of this zone are to be seen in a quarry about a mile W.S.W. of Baldock, which shows soft white chalk without flints, but including a band of nodular chalk with yellow stains ; the soft chalk contains *Terebratulina gracilis* var. *lata, Ter. striata,* small *Rhynchonella Cuvieri*, and other fossils.

Higher beds with a few flints and *Inoceramus Cuvieri* are seen in a pit south-east of Baldock.

There are two quarries in this zone near Royston, one east and one south-west of the town. That to the eastward is the deepest, and the beds shown are :—

	feet.
Thin-bedded chalk with scattered root-like and elongate flints	12
Layer of grey shaly marl.	
Massive thick-bedded chalk, with a line of scattered flints at the top	16
Layer of irregular knobby flints.	
Thick-bedded white chalk	8

Spondylus spinosus and *Discoidea Dixoni* were obtained here. The other quarry is not more than 25 feet deep ; it shows similar white chalk, with some flints and a thin layer of grey marl. *Spondylus spinosus* occurs here also with *Inoceramus Cuvieri* and *Terebratula semiglobosa.*

LIST OF FOSSILS FROM THE MIDDLE CHALK IN BEDFORDSHIRE AND HERTFORDSHIRE.

The following list has been compiled from several sources, and the particulars as to localities and collectors are given below.

Of the species from the *Rh. Cuvieri* zone, those numbered 1 are from the quarry near Pitstone, mentioned on p. 463, and were obtained by Mr. J. Rhodes, the fossil collector of the Geological Survey.

Those numbered 2 are from the quarry by Hitchin Station. They were collected at various times by Mr. W. Hill, and were identified by me. This list includes most of the characteristic zonal fossils, and the assemblage is similar to that in the same zone at Dover.

Column 3 includes a few species found by myself at Ashwell.

Of the fossils from the *Terebratulina* zone, those indicated by the figure 1 are species found by Mr. Rhodes at Coldharbour quarry, near Dunstable.

The second column shows those found in this zone near Luton. Most of the specimens are in the collection of Mr. J. Saunders and were named by me, but a few were obtained by Mr. Rhodes, and were named by Messrs. Sharman and Newton.

Those numbered 3 are from Hitchin, and were collected by Mr. Hill from the beds above the first line of flints in the quarries by the railway, and in Mr. Ransome's quarry further south.

Those numbered 4 were found by myself in the two quarries near Baldock.

———	Zone of Rhyn. Cuvieri.			Terebratulina Zone.			
Pisces.							
Lamna appendiculata, *Ag.*	–	–	–	–	2	–	–
Oxyrhina Mantelli, *Ag.*	–	–	–	–	2	–	–
Ptychodus decurrens, *Ag.*	–	2	–	–	–	3	–
„ latissimus, *Ag.*	–	–	–	–	2	–	–
„ mammillaris, *Ag.*	–	–	–	–	2	–	–
Fish remains	–	–	–	1	–	–	–
Cephalopoda.							
Am. [Pachydiscus] peramplus, *Mant.*	–	2	–	–	–	–	–
Rhyncholite (of Nautilus)	–	–	–	–	2	–	–
Lamellibranchiata.							
Avicula sp. (smooth)	1	–	–	–	–	–	–
Exogyra haliotoidea, *Sow.*	–	2	–	–	2	–	–
Inoceramus mytiloides, *Sow.*	1	2	3	–	2	–	–
„ „ var. problematica, *d'Orb.*	–	2	–	–	–	–	–
„ Cuvieri, *Sow.*	1	2	–	1	2	3	?
„ Lamarcki, *Park.*	–	–	–	1	–	–	–
„ sp. (square, smooth)	–	2	–	–	–	–	–
Lima granosa, *Goldf.*	–	–	–	–	–	–	–

——	Zone of Rhyn. Cuvieri.			Terebratulina Zone.			
Ostrea normaniana, *d'Orb.*	—	—	—	—	2	—	—
,, vesicularis, *Lam.*	—	2	—	—	2	—	—
Radiolites Mortoni, *Mant.*	—	—	—	—	2	—	—
Spondylus spinosus, *Sow.*	—	—	—	—	2	3	—
,, latus, *Sow.*	—	2	—	—	2	3	—
Brachiopoda.							
Rhynchonella Cuvieri, *d'Orb.*	1	2	3	—	—	3	4
,, ,, (small var.)	—	—	—	1	—	—	4
,, sp.	1	—	—	—	—	—	—
Terebratula semiglobosa, *Sow.*	1	2	3	1	2	3	4
Terebratulina gracilis, var. lata, *Eth.*	1	2	—	1	—	—	4
,, striata, *Wahl.*	—	2	—	—	—	3	4
Echinodermata.							
Cardiaster pygmæus, *Forbes*	—	2	—	—	—	—	—
Cidaris Merceyi, *Cotteau*	—	—	—	—	2	—	—
,, (spines)	—	2	3	—	2	—	4
Cyphosoma granulosum, *Goldf.*	—	—	—	—	2	—	—
Discoidea Dixoni, *Forbes*	—	2	—	—	2	3	—
,, minima, *Ag.*	—	2	3	—	—	—	—
Galerites castanea, *Brongn.*	—	2	—	—	2	—	—
,, subrotundus, *Mant.*	1	2	—	—	2	3	—
Hemiaster minimus, *Ag.*	—	2	—	1	—	—	—
Holaster planus, *Mant.*	—	—	—	—	2	—	—
Salenia granulosa, *Forbes*	—	—	—	—	2	—	—
Cephalites paradoxus, *Smith*	—	—	—	1	—	—	—
Ventriculites sp.	—	—	—	1	—	—	—

CHAPTER XXXVIII.

THE MIDDLE CHALK IN CAMBRIDGESHIRE AND THE NORTH-EAST OF ESSEX.

General Description.

The Middle Chalk occupies a tract of considerable width from the neighbourhood of Royston on the west to the valleys of the Cam and the Lin below Chesterford and Linton, lying partly in Cambridge and partly in Essex. Thence it rises into the Gog Magog Hills, and spreads north-eastward below the higher Chalk escarpment to Dullingham and Newmarket. For the sake of convenience we shall describe some sections near Royston in this chapter, though that town is really in Hertfordshire.

The zones of this area were established in 1880,* and were fully described in the Geological Survey Memoir on the Neighbourhood of Cambridge (1881). It was then that the name of Melbourn Rock was given to the rocky beds at the base of the zone of *Rhynchonella Cuvieri,* the name being taken from the little village of Melbourn, near Royston, where there are good sections of the beds that lie at the junction of the Middle and Lower Chalk. It must be remembered, however, that the Melbourn Rock of the Cambridge Memoir includes the sub-zone of *Actinocamax plenus,* which was subsequently separated.

A line of section drawn by Mr. W. H. Penning and myself through the Gog Magog Hills showed that the thickness of the beds from the base of the Melbourn Rock to the base of the Chalk Rock was about 230 feet, of which some 60 or 70 feet may be assigned to the lower zone and about 160 feet to the *Terebratulina* zone.

In 1881 the higher zone was divided into two parts, because the upper beds contained *Holaster planus, Micraster corbovis,* and *Spondylus spinosus,* which linked them, as was thought, more closely to the beds above than to those below. More recent researches however have shown that these species occur not infrequently in the upper part of what is generally recognised as the *Terebratulina* zone, and the bearing of this on the zonal nomenclature has been discussed on p. 360.

Throughout the greater part of Cambridgeshire the Middle Chalk lies almost horizontally, its easterly inclination being so slight as to be inappreciable in quarry sections, but south-east of Royston there is a remarkable line of flexure, probably accompanied by a fault. This flexure is exposed in a series of quarries; it appears to commence near Therfield, crosses the North Road (Ermine Street) about two miles south of Royston, and curves round by Newsells Bury, Smyth's End (Barley), Great Chishall and Heydon. At all these places the beds are bent into an anticline, the northern limb of which plunges down the slope of the escarpment. Whether they are cut off by a fault or whether the curvature is continued by a corresponding syncline we do not know, but there must be either a fault or a syncline along the lower slopes of the escarpment, as the chalk near Royston has normal southerly dips. If there is no fault, there would be a second outcrop of the Chalk Rock to the north of this series of exposures, but no such outcrop was found.

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* The Sub-divisions of the Chalk, Geol. Mag., Dec. 2, Vol. vii., p. 248 (1880).

† See "The Melbourn Rock and Zone of Belemnitella plena," by W. Hill and A. J. Jukes-Browne, Quart. Journ. Geol. Soc., Vol. xlii p. 216 (1886).

STRATIGRAPHICAL DETAILS.

Zone of Rhynchonella Cuvieri.—The outcrop of the Melbourn Rock enters Cambridgeshire near Ashwell Station, on the Hitchin and Cambridge Railway.

The upper part of this zone, with some of the overlying zone, is exposed in the large quarry in Morden Plantations. The upper level of this quarry shows :—

	feet.
Soil and chalk rubble	4
Bedded white chalk with a few flints	20
Tough yellowish rocky chalk	1
Rather soft white chalk, with scattered flints and a course of elongate finger-like flints 10 feet down. This chalk contains *Galerites subrotundus*, *Gal. castanea*, *Rhynchonella Cuvieri*, *Terebratula semiglobosa* and teeth of *Ptychodus*	12

The lower level shows :—

Chalk between two layers of flints	3
Tough yellowish chalk full of *Inoceramus mytiloides*, dipping eastward	15

The yellowish band in the upper level may perhaps be taken as the upper limit of the *Rh. Cuvieri* zone.

The base of the zone is exposed in a pit by the side of Ermine Street, more than a mile north of Royston, and the section as taken in 1885 was as follows :—

		feet.
	Soil and hard bedded chalk	6
Melbourn Rock.	Hard yellowish chalk with thin marly partings containing nodules	3½
	Hard nodular whitish chalk	3½
Lower Chalk.	Lenticular beds of marly chalk	2
	Hard marbled chalk, grey and white	1
	Grey marly chalk	1
	White chalk - seen for	6

The Melbourn Rock is also well exposed in the lime-kiln quarry south of Melbourn, thus :—

		feet.
	Soil and broken chalk	8
	Bedded whitish chalk	4
Melb. Rock.	Hard yellowish bedded chalk	4
	Hard rough nodular chalk, massive	3½
	Lower Chalk, marls, etc. (see p. 199)	32½

The Melbourn Rock, 8 or 9 feet thick, with some of the overlying chalk, is also exposed in the upper chalk pit on Foxton Hill, and being much weathered its nodular character is very apparent.

An exposure of the middle part of this zone occurs in a small pit by Stanmore Hall, west of Whittlesford, showing 8 or 10 feet of weathered rough lumpy chalk containing good typical specimens of *Rhynchonella Cuvieri.*

The Melbourn Rock is seen in the upper level of the large chalk-pit on Steeple Hill, north of Shelford, and the highest part of the zone in the pit below Little Trees Hill, near Vandlebury, the section in the latter being:—

	feet.
Chalk rubble - - - - - - - - - - -	3
Hard rocky chalk - - - - - - - - -	3
Greyish marl with hard nodules - - - - - - -	½
Bedded white chalk, with occasional flints and several thin layers of shaly marl - - - - - - - - -	18

Rhynchonella Cuvieri occurs in the Marl band. Another pit, showing a similar section, occurs on Missleton Hill, north-east of Wandlebury, where the bedded white chalk yields more fossils, *Rhynch. Cuvieri, Galerites subrotundus, Inoceramus mytiloides, Terebratulina gracilis* var. *lata,* etc. Similar chalk with the same fossils was exposed in the railway cutting a mile south-east of Great Wilbraham.

Terebratulina Zone.—The quarries in the lower part of this zone near Royston have been mentioned on p. 469. East of these there are few exposures till the valley of the Cam is reached. A pit by the cross roads at Duxford shows 20 feet of thin-bedded, platy white chalk, with a very few small flints and a thin seam of whitish marl. This is near the base of the zone. Near Ickleton there are two pits, one half a mile west and the other three-quarters of a mile S.S.W. of the village; these show thin-bedded white chalk with *Ventriculites, Inoceramus Cuvieri,* a species of *Micraster* and of *Scaphites.*

Still higher beds are shown in the large quarry at Great Chesterford, half a mile east of the church; the section here, as noted by Mr. Penning in 1876, was as follows:—

	feet.
Rather hard splintery chalk - - - - - - - -	18
Layer of whitish marl - - - - - - - - -	¼
Bedded white chalk, with a layer of flints about 5 or 6 feet below the marl - - - - - - - - - -	22

The upper beds contain *Terebratulina gracilis* var. *lata, Cidaris* spines, and a *Pecten.* In the lower part fossils are scarce.

North of Linton there is a quarry in thick-bedded white chalk without any flints, but yielding *Micraster Leskei, Holaster planus, Spondylus spinosus* and *Ventriculites.* This is in the upper beds of the zone.

Lower beds are seen in a cutting on the abandoned line of railway near Worsted Lodge. These consist of white chalk with many flints, mostly arranged in bands parallel to the bedding; they are very irregular in shape, and many of them are long, narrow, cylindrical and root-like. *Galerites subrotundus, Terebratulina gracilis* var. *lata, Rhynchonella* sp. (small), and *Inoceramus mytiloides ?* were found here. The same beds are also exposed in the next cutting to the north (Mutlow Hill). Some of the beds are firmer than the others and stand out in the weathered face.

A quarry in the central part of the zone is open near Westley Lodge, east of Six Mile Bottom Station on the Newmarket Line. In 1880 this showed:—

	feet.
White chalk without flints - - - - - - - -	12
Thin seam of grey marl.	
White chalk full of finger-like flints of various sizes, with some larger and thicker flints - - - - - - - -	5

Near Dullingham Railway Station is a pit in the higher part of the zone with *Micraster* and *Holaster planus*. It is about 20 feet deep, the upper 10 feet containing many flints of various shapes and sizes, but there are none in the lower part.

The highest beds of this zone are shown in a pit south-west of Westley Waterless and again in a quarry by Underwood Hall, north-west of Westley Waterless, where they include two thin layers of tabular or continuous flint.

The following list of fossils is based upon those given in the Memoir on the Neighbourhood of Cambridge, with a few alterations and additions:—

LIST OF FOSSILS FROM THE MIDDLE CHALK.

	Zone of R. Cuvieri.	Zone of Ter. gracilis.	
		Lower.	Upper.
Pisces.			
Protosphyræna ferox, *Leidy* - - -	x	–	–
Ptychodus decurrens, *Ag.* - - - -	x	–	–
Cephalopoda.			
Scaphites Geinitzi, *d'Orb.* - - - -	–	–	x
Lamellibranchiata.			
Exogyra sp. - - - - - - -	x	–	–
Inoceramus Brongniarti, *Sow.* - - -	–	–	x
,, Cuvieri, *Sow.* - - -	–	–	x
,, mytiloides, *Sow.* - - -	x	x	–
Ostrea vesicularis, *Lam.* - - - -	x	x	x
,, semiplana ? *Sow.* - - -	–	–	x
Pecten Beaveri, *Sow.* - - - -	–	–	x
Spondylus latus, *Sow.* - - - -	x	x	x
,, spinosus. *Sow.* - - - -	–	–	x

List of Fosssls from the Middle Chalk—*Continued.*

———	Zone of R. Cuvieri.	Zone of Ter. gracilis.	
		Lower.	Upper.
Brachiopoda.			
Rhynchonella Cuvieri, *d'Orb.*	x	x	x
,, mantelliana, *Sow.*	x	–	–
,, plicatilis, *Sow.*	–	x	x
,, reedensis, *Eth.*	–	–	x
Terebratula semiglobosa, *Sow.*	x	x	x
Terebratulina gracilis, var. lata, *Eth.*	x	x	–
,, striata, *Wahl.*	x	x	–
Annelida.			
Serpula antiquata ? *Sow.*	x	–	–
Echinodermata.			
Cidaris dissimilis, *Forbes*	x	x	–
,, hirudo, *Sorig.*	x	–	–
,, sceptrifera ? *Mant.* [or serrifera]	–	–	x
Cyphosoma radiatum, *Sorig.*	–	–	x
Discoidea Dixoni, *Forbes*	–	x	–
Galerites castanea, *Brongn.*	x	–	–
,, subrotundus, *Mant.*	x	x	–
Holaster planus, *Mant.*	–	–	x
Micraster Leskei, *Desm.*	–	–	x
,, præcursor, *Rowe*	–	–	x
Actinozoa.			
Parasmilia centralis, *Mant.*	–	x	–
Spongida.			
Ventriculites impressus, *T. Smith*	–	–	x
,, mammillaris, *T. Smith*	–	–	x

CHAPTER XXXIX.

THE MIDDLE CHALK IN SUFFOLK AND NORFOLK.

GENERAL DESCRIPTION.

The Middle Chalk of Suffolk has not yet been fully explored by anyone. Even the outcrop of its basement bed, the Melbourn Rock, has only been traced through a portion of the county, namely, from Mildenhall to Lakenheath, and this was done by Mr. Hill and myself in 1886.* Little is known of the higher beds, and no exposure of Chalk Rock or of beds referable to that horizon has yet been discovered north of the railway from Newmarket to Bury St. Edmunds.

Rather more is known about this division in Norfolk, for the Melbourn Rock has been traced continuously through the county, and its course is indicated on the maps of the Geological Survey. Moreover, Dr. Barrois visited West Norfolk in 1875, and recognised the zones established by him at several localities mentioned in his "Recherches" (1876). Finally, Mr. Hill made some special exploration of the Middle Chalk in the north-western portion of the county (Sheet 69), and his observations have been published in the memoir on that sheet.†

In Suffolk it is probable that the zones of *Rhynchonella Cuvieri* and of *Terebratulina* have a combined thickness of about 200 feet, but they certainly become thinner northwards, and in the northern part of Norfolk their combined thickness is probably less than 100 feet.

What relation the beds which contain *Holaster planus* in Norfolk bear to the zone of *H. planus* on the borders of Cambridge and Suffolk it is difficult to say. Seeing, however, that *Holaster planus* makes its appearance some distance below the Chalk Rock near Newmarket, it is possible that the chalk which contains that fossil in Norfolk represents the highest part of the *Terebratulina* zone as well as the Chalk Rock beds.

STRATIGRAPHICAL DETAILS.

Zone of Rhynchonella Cuvieri.

When the Bury and Soham Railway was being made in 1879, Melbourn Rock was recognised by Mr. Whitaker in the cutting south-west of Snailwell, and it is traversed again by the railway to

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* See Quart. Journ. Geol. Soc., Vol. xliii. p. 563.

† Geology of the Borders of the Wash, Mem. Geol. Survey (1899).

Mildenhall in the cutting south of Worlington House. A quarry near Worlington Heath Farm exposes the top of it, the section seen by myself and Mr. Hill in 1886 being :—

	feet.
Gravelly soil and rubble	4
Hard nodular whitish chalk, full of *Inoceramus mytiloides* and *Rhynchonella Cuvieri*	4
Thin seam of greenish grey marl.	
Hard nodular rocky chalk, white with greenish marl between the lumps seen for	3
Talus hiding lower beds	4

The town of Mildenhall stands on the chalk of this zone, and hard, shelly, yellowish chalk, containing *Rhynchonella Cuvieri, Inoceramus mytiloides* and *Galerites subrotundus,* is exposed in a small pit at the eastern end of the town.

At Lakenheath, north-east of the church, there is a large quarry exposing about 30 feet of hard chalk, which weathers to the peculiar lumpy or nodular surface characteristic of exposures in this zone. At the lowest level near the entrance harder, more nodular, shelly chalk was seen. The fossils found in this quarry were *Am.* [*Pachydiscus*] *peramplus, Inoceramus mytiloides, Terebratula semiglobosa, Rhynchonella Cuvieri,* and *Galerites subrotundus.*

North of the Brandon River, which forms the boundary between Suffolk and Norfolk, the first section is the large chalk pit at Methwold, and the following description has been given by Mr. Hill and myself in the paper above mentioned :—

	feet.
Soil, gravel and disturbed chalk	4
Hard lumpy chalk with two thin layers of greyish marl at the base	8
Hard yellowish nodular chalk with *Rhynch. Cuvieri* and other fossils	25

The floor of the pit is probably on the upper part of the Melbourn Rock. The following fossils were found in the nodular chalk :—

Am. [*Pachydiscus*] *peramplus.*
Inoceramus mytiloides.
Rhynchonella Cuvieri.
Terebratula semiglobosa.
Cardiaster pygmæus.
Galerites subrotundus.
Hemiaster minimus.

The Melbourn Rock is exposed in a quarry at Whittington (see p. 211) whence Mr. C B. Rose obtained *Am.* [*Pachydiscus*] *peramplus* two feet in diameter. It is seen again in the pit south of Barton Bendish, and in two quarries at Marham, all of which show the junction of the Lower and Middle Chalk, and have been mentioned on a previous page (see p. 212).

What appears to be the lower part of the zone of *Rhynchonella Cuvieri* is exposed in the quarry between Hillington and Congham ; this is worked in two levels, and the upper one is about 20 feet deep in hard, whitish chalk with yellowish stains, lying in thin beds and weathering into platy pieces; it is less nodular than usual, but Mr. Hill found an echinoderm which appeared to be *Galerites subrotundus*. The lower level showed 4½ feet of similar hard, whitish chalk overlying a thin layer of buff-coloured marl and 14 feet of whitish Lower Chalk (see p. 213).

At Sherborne, less than a quarter of a mile north of the church, hard yellowish nodular chalk can be seen in a small exposure by the roadside, close by an old quarry which is now overgrown and talused. This is doubtless the quarry mentioned by Professor Barrois, in which he recognised "the hard nodular bed which throughout England occurs at the base of the zone of *Inoceramus labiatus*,"* and which is now called the Melbourn Rock. From it he obtained the following fossils:—*Am.* [*Acanthoceras*] *nodosoides*, *Ostrea vesicularis*, *Inoceramus mytiloides* (=*labiatus*), *Rhynchonella Cuvieri*, and *Discoidea minima*.

Whitish nodular chalk is shown in the cutting east of Sedgeford station, and what is probably the highest part of the zone in a quarry half a mile south-east of Sedgeford, though Dr. Barrois referred the latter exposure to the *Terebratulina* zone.

The Melbourn Rock is well exposed at the top of the large quarry at Heacham, 6 feet of hard yellowish nodular rock, well bedded, but weathering into thin, platy pieces along lines and seams of greenish marly material. Its base is a well-marked plane, resting directly on hard white chalk, without the intervention of any marly layer (see p. 213).

Another good exposure occurs in the quarry north-east of Barret Ringstead Farm, and shows the following beds:—

		feet.
Middle Chalk.	Hard chalk, broken and rubbly - - - -	6
	Hard rough creamy white chalk - - - -	3
	Very hard rough yellowish nodular chalk in two thick beds (Melbourn Rock) - - - -	7
Lower Chalk.	Dull white chalk in thin beds with seams of grey marl - - - - - - - -	12
	Greyish-white chalk in thicker beds - - -	4
		32

Rhynchonella Cuvieri and *Inoceramus mytiloides* are common in the rough and rocky chalk.

Terebratulina Zone.

No exposure of this zone has yet been recorded in Suffolk, south of the Lark, though it doubtless occupies a considerable tract of country by Kentford, Herringswell, Tuddenham, and Little Barton.

Mr. H. Woods, of Cambridge, examined some of the exposures in the Valley of the Lark during 1901, and has kindly communicated the following notes thereon:—

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*Recherches sur le Terr. Crét. Sup., p. 160.

A chalk-pit about a quarter of a mile north of the church at Icklingham St. James shows about 12 feet of rather hard thin-bedded chalk, with a few small flints. The only fossils seen were *Terebratulina.* Another pit is opened near Avenue Farm, about a mile north-west of the church, and this shows about 7 feet of similar chalk containing a few fossils which, however, are not easy to extract. Those found were *Terebratula semiglobosa, Rhynchonella Cuvieri* (small circular variety), *Terebratulina* (*?lata*), *Plicatula Barroisi* and *Inoceramus Lamarcki ?.*

North of the river Lark the surface of this part of the Chalk is often deeply covered with blown sand, but there are places where chalk comes to the surface. A quarry by the high road, east of Eriswell, is opened in soft white chalk without flints, but containing *Galerites subrotundus* and some *Inocerami;* it probably belongs to the lower part of this zone.

In the southern part of Norfolk the only exposure of this zone seen by Mr. Hill or myself is that of a quarry at the western end of Northwold, about three miles south-east of Stoke Ferry. It shows about 36 feet of soft but firm white chalk, well-bedded, and including several thin layers of grey marl. The lower beds are the firmest, and have been quarried for building purposes; they yielded *Galerites subrotundus, Inoceramus mytiloides, Terebratula semiglobosa,* and a small *Rhynchonella* (? var. of *Cuvieri*). These beds probably form the top of the *Rh. Cuvieri* zone; the upper 12 feet are softer, and contain some scattered flints.

Exposures of this zone could doubtless be found along the country north of Gooderstone, and east of the outcrop of the Melbourn Rock, but no one has looked for them.

In the more northern part of Norfolk the chalk of this zone partakes of the prevailing tendency of all the lower beds to become harder and more compact, the thickness at the same time becoming less. Moreover, the fossil which is so common in more southern counties seems very rare in Norfolk, so that it is often difficult to be certain of the zonal horizon of any small exposure.

In the memoir describing the north-western part of Norfolk and explanatory of sheet 69 (old series),* many pits are mentioned which seem to be in this zone, but only three of them are worth special notice.

The first of these is at Fring, a little south-east of the church, and shows about 30 feet of solid white chalk, with a layer of flints near the bottom, and two others in the upper part. The only fossils found were *Rhynchonella Cuvieri* and *Galerites subrotundus.*

The second is a quarry south of Ringstead St. Andrew, near Hunstanton, which is about 25 feet deep in hard chalk, veined irregularly with grey marly material, and containing a few grey flints.

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*Geology of the Borders of the Wash, Mem. Geol. Survey, 1899.

From this pit Mr. Rhodes obtained a few fossils, which have been identified as follows:—

Inoceramus mytiloides.
Terebratula semiglobosa.
Rhynchonella Cuvieri.
Holaster (? planus).
Galerites subrotundus.
Discoidea minima.
Cardiaster (? pygmæus).
Cidaris spines.

The third quarry is half-a-mile south of Thornham, and shows about 30 feet of hard veiny chalk with several layers of large grey flints; this is probably in the upper part of the zone.

The following is a list of such fossils as have been found in the Middle Chalk of these counties, compiled partly from Professor Barrois' work, but chiefly from the Survey Memoirs on Sheets, 51, 65, and 69:—

———	Zone of R. Cuvieri.	Zone of T. gracilis.
Cephalopoda.		
Ammonites [Acanth.] nodosoides, *Schlüter* - -	x	–
" [Pachydiscus] peramplus, *Mant.* -	x	–
" [Acanth] rusticus ? *Sow.* - - -	x	–
" large smooth sp. - - - - -	x	–
Lamellibranchiata.		
Inoceramus Brongniarti, *Sow.* - - - - - -	?	x
" Cuvieri, *d'Orb.* - - - - - -	x	x
" Lamarcki, *Park.* - - - - - -	–	x
" mytiloides, *Mant.* - - -	x	x
Ostrea vesicularis, *Lam.* - - - - - -	x	–
Plicatula Barroisi, *Peron* - - - - - -	–	x
Brachiopoda.		
Rhynchonella Cuvieri, *d'Orb.* - - - - -	x	x
" " (small var.) - - - -	x	x
Terebratula semiglobosa, *Sow.* - - - - - -	x	x
Terebratulina striata, *Wahl.* - - - - - -	x	–
" gracilis, var. lata, *Eth.* - -	–	x
Echinodermata.		
Cidaris hirudo, *Sorig.* - - - - - - -	x	–
" sp. - - - - - - - - - -	–	x
Cardiaster (? pygmæus, Forbes) - - - - -	–	x
Discoidea minima, *Ag.* - - - - - - -	x	–
Galerites subrotundus, *Brongn.* - - - -	x	x
Holaster planus, *Mant.* - - - - - - -	–	?

CHAPTER XLI.

THE MIDDLE CHALK IN LINCOLNSHIRE.

General Description.

The marly band which forms the top of the Lower Chalk throughout Lincolnshire is succeeded by beds of hard greyish or yellowish grey chalk in well-marked courses, which are separated by thin layers of grey shaly marl, some of which contain loose nodules of hard chalk. This greyish chalk is so full of fragments of *Inoceramus* shell that it is often quite gritty to the touch, and more or less perfect shells of *Inoceramus mytiloides* are very common, so that in the Memoir on the Geology of East Lincolnshire (wherein it was first described, 1887) it was indicated as the zone of *Inoc. mytiloides*. *Rhynchonella Cuvieri*, however, is also common, so that there is no need to give the zone another name. Its thickness varies from 10 to 13 feet. There is no bed which could be regarded as specially representing the Melbourn Rock, but the whole seems to be a condensed equivalent of the zone of *Rh. Cuvieri.*

The overlying *Terebratulina* zone is much more sharply defined from that of *Rhynch. Cuvieri* than it is in more southern counties; for its lowest bed is a thin course of white compact chalk, never more than 6 inches thick, which is traversed by a system of nearly straight vertical joints, so that the bed breaks up into a set of rectangular blocks; these joints are so numerous that, when a weathered exposure is seen, the bed seems broken into a number of small blocks like columns or bricks set on end, and this has suggested the name of "the columnar bed." As it generally rests on a layer of shale or shaly chalk, the horizontal lines of the one contrast strongly with the vertical lines of the other.

The appearance of such a section is illustrated in Fig. 81, which was sketched in a chalk pit south of Claxby.

Section in a Chalk-pit south of Claxby.

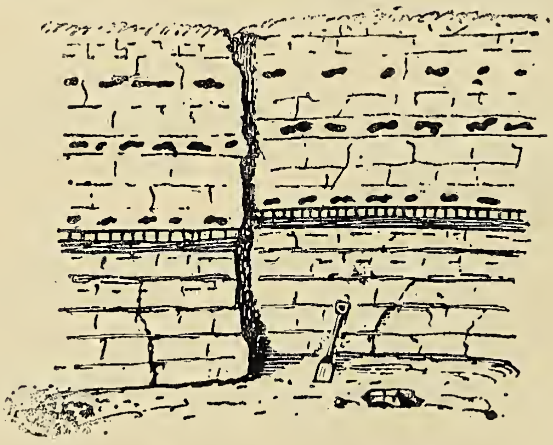

Fig. 81.—Junction of the *Terebratulina* Zone with that of *Rhynch. Cuvieri* south of Claxby.

		feet.
d.	White chalk with three layers of flint nodules	12
c.	The columnar bed, jointed vertically	0½
b.	Greyish laminated chalk	0½
a.	Greyish chalk without flints	8

The "columnar bed" is almost always clearly discernible, though in some places the vertical joints are less numerous than in others.

The overlying chalk is of a pure creamy-white compact, evenly bedded, and containing nodules of grey flint, which are generally arranged in layers, though in some of the higher beds there are scattered flints of irregular elongate shape between the regular courses of flints. These grey flints adhere closely to the chalk in which they are embedded, and are traversed by the same joint planes as the surrounding chalk, so that as the rock is quarried and breaks away along these joint planes the fracture passes evenly through both chalk and flint, each portion of the flint nodule remaining in the block of chalk to which it belongs. In consequence of this peculiarity every layer of flint exposed in a quarry is visible at a glance. Thin continuous layers, or floors, of flint occur occasionally, but are not numerous. Thin seams of dark grey marl, or marly clay, are of frequent occurrence. Fossils are extremely scarce, with the exception of *Inocerami* belonging to species which are generally referred to *I. Brongniarti* and *I. Cuvieri*. The characteristic *Terebratulina* has not yet been found in this county.

With respect to the thickness of this chalk with nodular flints, which evidently represents the *Terebratulina* zone, we can only say that it is probably from 70 to 80 feet. It is only recently that Mr. Hill has found evidence of the zone of *Holaster planus* near Louth, and has consequently proved that there is Upper as well as Middle Chalk to the north of that town.* This discovery excludes from the Middle Chalk most of the higher beds which contain thick continuous floors of flint, and restricts it to the chalk with nodular flints as above described.

The small thickness of the zone of *Rh. Cuvieri*, and the appearances at the top of it, suggest that the plane of division between it and the overlying zone represents the lapse of a certain period of time, during which no deposition took place, even if there was not some removal of material by current action.

STRATIGRAPHICAL DETAILS.

Zone of Rhynchonella Cuvieri.

The chalk of this zone is exposed in many of the chalk pits which have been opened along the range of the Lincolnshire Wolds. Details of these will be found in the memoirs descriptive of Sheets 84 and 86 of the Geological Survey map, but a few of the best sections are given below.

Near the southern end of the Wolds there is a good section through these beds in the quarry north-west of Claxby. A fault with a throw of about 10 feet runs through this pit, and the beds measured on the east side of it in 1879 were:—

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* See "Note on the Upper Chalk of Linconshire," by W. Hill, in Geol. Mag., Dec. 4, Vol. ix., p. 404 (1902).

		feet.
Terebratulina Zone.	Soil and chalk rubble - - - - - - -	3
	Hard white chalk with a layer of flint nodules, which are grey inside - - - - - - -	13
	White chalk with vertical joints and a thin seam of marl at the base - - - - - - - -	0½
Zone of *Rhynch. Cuvieri.*	Hard greyish chalk in beds about a foot thick with marly partings - - - - - - - -	8
	Loose grey marl with small nodules of hard chalk -	0½
	Greyish white chalk in two beds - - - -	2
Lower Chalk.	Loose grey marl, enclosing hard yellowish nodules	1
	Hard grey chalk - - - - - - -	6

Its thickness here, therefore, is only between 10 and 11 feet, and is about the same in a quarry south-east of Calceby.

In the large quarry at South Thoresby the zone is a little thicker; here the beds dip to the south-west and the Middle Chalk is thus brought into the western face of the pit, along which the following measurements were taken in 1879:—

		feet.
Middle Chalk.	6. White chalk with flints - - - - - -	5
	5. Layer of white chalk about 6 inches, broken by frequent vertical joints (Columnar Bed) - -	0½
	4. Layer of grey rubbly shale - - - - -	0½
	3. Hard buff coloured chalk, very shelly and containing *Inoceramus mytiloides*, in beds from 12 to 18 inches thick - - -	12
Lower Chalk.	2. Variegated marl, red, grey, green, and buff	1½
	1. Hard pinkish white chalk (see p. 220) - -	3

A similar section is seen in a chalk-pit near Swaby, of which Fig. 82 is a sketch, the numbers referring to the beds above mentioned.

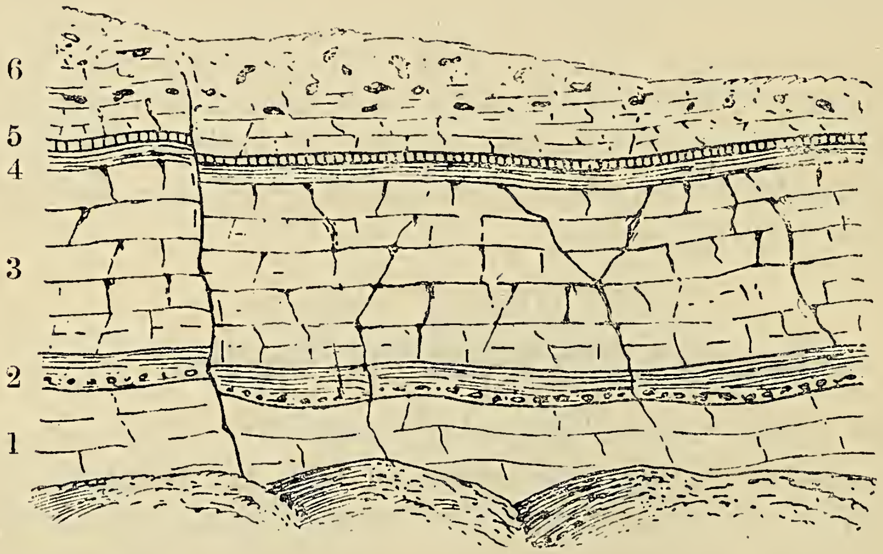

Fig. 82.—Sketch in a Chalk-pit near Swaby.

Near Louth this zone is exposed in several large quarries, both on the south and on the north side of the town. It varies from 12 to 15 feet in thickness, and the following is the section visible in Mr. Clapham's quarry by the London road south of Louth:—

		ft.	in.
Terebratulina Zone.	White chalk in thick beds with layers of flints	30	0
	Similar chalk, some beds very hard	12	0
	Hard white chalk, not much jointed	0	6
Zone of *Rhynch. Cuvieri.*	Layer of loose grey shale	0	6
	Hard shelly chalk in beds from 12 to 18 inches thick, separated by layers of grey shale	8	0
	Buff coloured sandy shale with nodules of hard chalk (*Inoceramus mytiloides*)	0	6
	Hard greyish chalk, with shaly partings	4	0
Grey and purple shaly marl (Belemnite Marl).			

The same succession can be seen in Mr. Paddison's quarry north of Louth, and again in a quarry at Elkington Pasture, about a mile W.N.W. of Louth.

Near Caistor this zone is well shown in a quarry by the windmill south-east of the town, as below.—

		ft.	in.
Soil and chalk rubble		3	0
Hard white chalk with two layers of flints		6	0
Zone of *Rh. Cuvieri.*	Shale and shaley chalk	0	9
	Hard greyish chalk in beds about a foot thick, with partings of grey shale	11	0
Soft grey shale (seen at one place).			

The same beds are exposed in two pits near Rothwell, one half a mile south-east, and the other W.N.W. of the village; the beds of greyish chalk are divided by layers of yellowish marly shale from 4 to 6 inches thick, containing small loose nodules or lumps of chalk. From these localities I obtained *Am.* [*Pachydiscus*] *peramplus* (young), *Inoceramus mytiloides,* and *Rhynchonella Cuvieri.*

The whole zone is well exposed in the large quarry north-east of South Ferriby, part of which section has been given on p. 222; the details of the upper part will be found on p. 484.

Terebratulina Zone.

This zone is found along the whole length of the Lincolnshire Wolds, but it is often cut through by the deep valleys which traverse the hills, and consequently it is divided and partitioned out into a number of irregular outliers and patches of various sizes. There are many exposures, all the most important of which have been noted in the memoirs of the Geological Survey already published,* so that we only need mention a few of the largest and best sections.

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*Geology of East Lincolnshire, by A. J. Jukes-Browne, 1887; Geology of the Country around Lincoln, by W. A. E. Ussher, A. J. Jukes-Browne and Aubrey Strahan, 1888; Geology of Parts of North Lincolnshire and South Yorkshire, by W. A. E. Ussher and others, 1890.

The first of these, exposing the base of the zone, is situate about a quarter-mile west of Ulceby, near Alford, and shows :—

		feet.
Terebratulina Zone.	White chalk in rather thick beds with four layers of grey flints and a layer of rubbly chalk at the base - - - - - - - - - -	22
	Thin-bedded chalk with scattered flints - - - -	8
	White chalk in thin beds with a layer of grey flints near the base - - - - - - - - -	2½
	Hard chalk jointed vertically and breaking into columnar fragments (Columnar bed see p.).	0½
Zone of *Rhynchonella Cuvieri*.—Hard grey chalk weathering into shale - - - - - - - -		2

Higher beds come in to the east of Ulceby along the eastern border of the Wolds (here very narrow) by Well, Rigsby, and Haugh. They are exposed in a quarry north-west of Wellchurch, which is about 27 feet deep, and from which *Inoceramus Cuvieri* and a small round variety of *Rhynchonella Cuvieri* have been obtained. A still deeper section is shown in the large quarry by the main road, about a mile W.S.W. of Alford railway station. In this the following beds are seen :—

	feet.
Soil and chalk rubble - - - - - - - - - -	2
Broken chalk, with a layer of grey flints - - - - -	3
White chalk, rather soft, in thick beds, with scattered elongate flints - - - - - - - - - - -	8
Layer of dark-grey marly clay.	
Massive white chalk with a layer of large flints - - -	6
Harder white chalk in three beds, no flints - - - - -	5
Layer of dark clay resting on an uneven iron-stained surface.	
White chalk in three beds, with scattered flints - - -	6
Thin continuous seam of flint, nearly black.	
White chalk evenly bedded with a layer of large nodular flints - - - - - - - - - - seen for	7
	37

The beds dip at 4° or 5° to the westward. There are several small displacements rendered conspicuous by the interruption of the layers of clay and flint, as indicated in Fig. 83, which represents part of the northern face where a small trough fault is seen. Fossils are very scarce.

There are two quarries near Haugh in beds which are probably rather lower, and have yielded *Inoceramus Cuvieri* and *Rhynchonella Cuvieri*. Other pits exist near Belleau, Muckton, and Cawthorpe, the last being more than 40 feet deep, and showing 4 or 5 layers of grey flints. The base of the zone, resting on that of *Rhynch- Cuvieri*, can be seen in a pit half a mile south-west of Cawthorpe, and in another by the side of the main road to Louth, about a mile west of the same village, and again in a pit 3 furlongs S.S.W. of Tathwell.

The chalk of the *Terebratulina* zone is quarried for manufacture into whiting at the place called " Saturday Pits " between Cawthorpe and Louth. The chalk seen is white and tough, in massive beds 2 or 3 feet thick, with courses of grey flints ; it is quarried in two levels, and near the top of the lower one is a layer of grey clay; the beds below this layer are harder and grittier, *i.e.*, more full of *Inoceramus* shell, than those above, which are consequently the most suitable for the manufacture of whiting.

The section in Mr. Clapham's quarry at Louth, showing some 40 feet of this chalk, has been given on a previous page. West of Louth some of it is exposed again in a quarry half a mile west of Bunkers, and still further west the base of the zone with the usual " columnar bed " was observed in a small pit S.S.E. of the farm in Welsdale Bottom (Sheet 83.)

Still farther north (within the limits of Sheet 86) the base of the zone, presenting similar features, is exposed in several pits near Rothwell, another half a mile south-east of Cabourn church, and again in one west of Swallow.

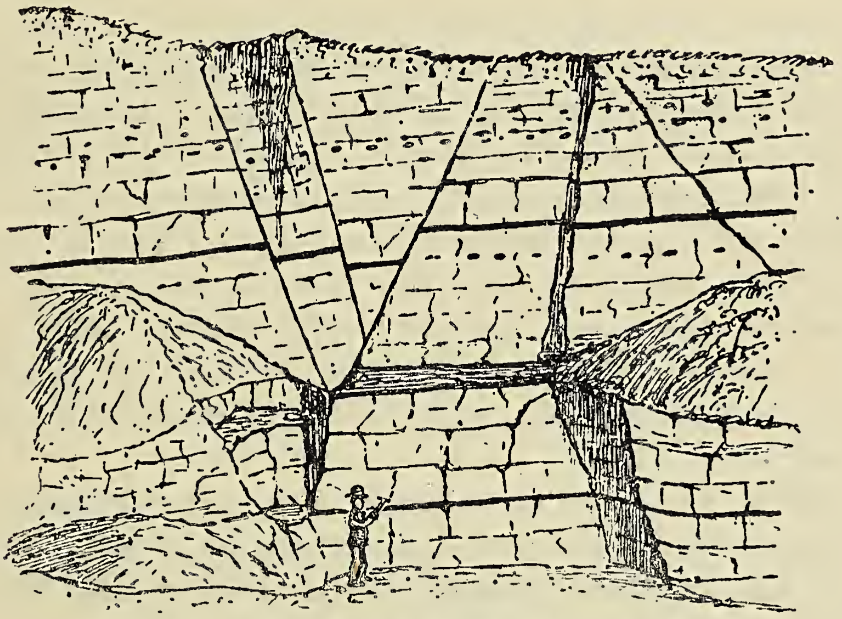

Fig. 83.—Sketch in a chalk pit near Alford.
a=seam of black flint. *b*=seam of grey clay.

West of Melton Ross there is a large quarry worked on both sides of the railway, and exposing some thickness of this chalk which is used for the manufacture of whiting. Mr. Hill informs me that it now shows about 60 feet of white chalk with grey flints, the upper part lying in thick, massive beds, the lower part in thinner beds with marly partings. The chalk is full of fragments of *Inoceramus* shell,and *Inoceramus Cuvieri* is a common fossil ; *Rhynchonella Cuvieri* was also found, but he saw no *Inoc. mytiloides,* so that the whole appears to be above the zone characterised by that fossil.

Another quarry half a mile north of Melton Ross was also visited by Mr. Hill in 1899, who reports it as showing about 20 feet of chalk with grey flints, less shelly than that at the Whiting Works, and probably in rather higher beds. He found an *Inoc. Cuvieri* and a small *Rhynchonella.*

The base of the zone, with some of the underlying chalk without flints, was seen by Mr. Fox-Strangways in a quarry about 40 feet deep in Elsham Church Wood, and again in a pit at the upper cross-roads near Horkstow.

The fine section in the large quarry near South Ferriby has already been mentioned (see p. 222), but the details of the upper part may now be given so far as the face was accessible for measuring; these are—

		feet.
Terebratulina Zone.	Hard white chalk with layers of grey flints, lying in beds of unequal thickness and divided into massive blocks by irregular joints	about 35
	Compact cream coloured chalk	2
Zone of *Rhynch. Cuvieri.*	Layer of shaly chalk and marl	0½
	Hard rough yellowish chalk, full of broken *Inoceramus* shell, divided into regular beds, a foot or more thick, by partings of shaly marl	10½
	For the lower beds see p. 222.	
	About	48

The higher beds of the *Terebratulina* zone crop out between Ferriby and Barton, and are probably exposed in some of the pits which are mentioned by Mr. Reid,* though we have not been able to verify this supposition by an actual inspection of them. Mr. Reid mentions a pit near the farm one mile east of Ferriby Hall, which exposes chalk with nodular grey flints, and another in similar chalk half a mile north-east of Grange Farm. Again "west of Barton, a pit shows 50 feet of chalk with a few scattered flint nodules throughout. Dip S.S.E. Small faults with downthrow to the north are visible."

The Middle Chalk of Lincolnshire has not yielded many fossils, though many quarries were searched both by myself and by Messrs. Allen and Rhodes in their capacity as fossil collectors. The following is a list of such as have been recorded:—

———	Zone of Rhynch. *Cuvieri.*	*Terebratulina* Zone.
Am. [Pachydiscus] peramplus *Mant.* (Rothwell)	x	–
,, sp.	x	–
Inoceramus Brongniarti, *Sow.*	–	x
,, Cuvieri, *Sow.*	x	x
,, involutus ? *Sow.* (Haugh)	–	x
,, mytiloides, *Sow.*	x	–
Ostrea vesicularis, *Lam.*	x	x
Rhynchonella Cuvieri, *d'Orb.*	x	x
,, lineolata ? *Phil.* (Rigsby)	–	x
Terebratula biplicata ? *Sow.*	x	x
,, semiglobosa, *Sow.*	x	x
Holaster sp.	x	–

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* Geology of Parts of North Lincolnshire, Mem. G. S., p. 127.

CHAPTER XLI.

THE MIDDLE CHALK IN YORKSHIRE.

General Description.

It might have been expected that the chalk of South Yorkshire would have been merely a continuation of that of Lincolnshire, but with respect to the Middle Chalk this is not the case, for differences present themselves as soon as we have crossed the Humber, not only in the lower zone of *Rhynchonella Cuvieri* but also in that of *Terebratulina.*

The lower beds of the *Rhynch. Cuvieri* zone are an almost exact counterpart of the beds found at the same horizon in Lincolnshire, consisting of rough, yellowish, shelly chalk in beds of no great thickness for 13 or 14 feet. This, however, is succeeded by white chalk in thicker beds, sometimes without flints and sometimes with flints, scattered or in layers, but this white chalk is not like that which succeeds in Lincolnshire, being rougher and containing *Inoceramus mytiloides.* Of this chalk there is 26 feet at Hessle, and apparently about 50 near South Cave.*

The *Terebratulina* zone also becomes somewhat thicker, though by how much it is thicker in South Yorkshire we do not yet know. It also develops near the base one or two beds of very hard compact chalk or chalky limestone, which bear a certain resemblance to the Chalk Rock of more southern counties, but do not contain nodules of any kind. In other respects the chalk of this zone resembles that of Lincolnshire, containing similar grey flints, with occasionally a thin seam of continuous flint and frequent layers of grey marl. It is, however, rather more fossiliferous, both *Ter. gracilis* var. *lata* and *Galerites subrotundus* occurring as well as the common *Inocerami—i.e., I. Brongniarti* and *I. Cuvieri.*

Mr. Hill's recent observations, which he allows me to incorporate in this chapter, show that the change from the *Terebratulina* zone (Middle Chalk) to the *Hol. planus* zone (base of Upper Chalk) is gradual, and similar to that in Lincolnshire.

They also throw light on a point which has given rise to some difference of opinion, and that is the position of the beds containing *Inoceramus mytiloides.* Professor Barrois correctly recorded this fossil under the name of *Inoc. labiatus* from the lowest part of the *R. Cuvieri* zone, and *Inoc. Brongniarti* from the overlying chalk with flints. The Rev. J. F. Blake maintained that the shell in the lower beds was *I. Cuvieri*, and that *I. mytiloides* occurred at a higher horizon in the chalk with flints.* The real facts seem to be that *I. mytiloides* occurs through a greater thickness of chalk than Professor Barrois at first supposed, ranging up into chalk with flints, but that it nowhere occurs abundantly above the chalk with *I. Cuvieri*, as Mr. Blake supposed; that the commonest forms in the *Terebratulina* zone are those which have been referred to *I. Cuvieri* and *I. Brongniarti*; but that *I. mytiloides* and a species resembling *I. undulatus* also occur.

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* This statement is based on information obtained recently by Mr. W. Hill, see p. 480.

Mr. Blake divided the lower part of the flint-bearing chalk into (1) creamy chalk with nodular flints, and (2) slaty chalk with thin flints, grouping both into a zone of *Inoceramus mytiloides.* This we cannot agree with, for most of it undoubtedly belongs to the *Terebratulina* zone, and in all probability much of the slaty chalk belongs to that of *Holaster planus.*

Mr. Blake estimated the thickness of his zone of *Inoc. mytiloides* at 200 feet, and, if we subtract 50 feet for the "slaty chalk," we shall have 150 feet for the thickness of the Middle Chalk in the northern part of the area; according to Mr. Lamplugh's estimates, however, it is more likely to be 200 feet, for he considers the total thickness of the flint-bearing chalk in the northern cliffs to be 460 feet, and it is not likely that more than 250 feet of this thickness is assignable to the Upper Chalk (zones of *H. planus* and *Micrasters*).

STRATIGRAPHICAL DETAILS.

There is an excellent section of the lower part of the Middle Chalk in the large quarries west of Hessle Station. The following notes of the section were made by myself in 1880 :—

		ft.	in.
Terebratulina Zone 25 feet.	Chalk rubble - - - - - - - -	2	0
	Pure white chalk, rather hard, with a layer of large nodular grey flints - - - - - - -	6	0
	Continuous layer of greyish-white flint, stained yellowish in places by iron - - - -	0	4
	Hard compact semi-crystalline limestone, tinged with yellow - - - - - - - -	2	0
	Soft chalk, with horizontal strings of grey marl	0	9
	Massive white chalk with large flints near the base	6	0
	Thin seam of clay.		
	White chalk with flints - - - - - -	2	0
	Thin seam of clay.		
	White chalk with flints of irregular elongate shapes, *Inoceramus Brongniarti* - - -	6	0
Zone of *Rh. Cuvieri* 36 feet.	Layer of dark clay - - - - - - -	0	2
	White chalk without flints, in beds from 2 to 3 feet thick, *Inoceramus mytiloides* - - -	26	0
	Rough yellowish chalk in thinner beds, with *Inoceramus mytiloides*, seen in excavation below the level of the rails, but base not exposed - - - - - - - -	10	0
		61	3

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* Proc. Geol. Assoc., Vol. v. p. 251. (1878).

It will be seen that the above succession is very different from anything seen in Lincolnshire. The beds seen below the line are comparable with those which occur in that county above the Belemnite marl, and are clearly referable to the *Rh. Cuvieri* zone; the next 26 feet seem to be a sudden expansion of that zone, and the succeeding beds up to the course of hard limestone differ greatly from the lower part of the *Terebratulina* zone, as seen in Lincolnshire, though they doubtless belong to it. I suggested in 1890 that it seemed "as if the sharp demarcation which prevails in Lincolnshire between the zone of *Rhynch. Cuvieri* and that of *Terebratulina gracilis* were here bridged over by the occurrence of passage beds."

The Rev. J. F. Blake gave some account of this quarry in 1878 (op. cit. p. 252), and remarked that "there are three distinct bands in it, known to the workmen, and quarried for different purposes. The lowest bed [or part] is worked for whiting, as it is entirely free from flints. . . . It is this that produces the great number of shark's teeth (*Ptychodus mammillaris*) for which the quarry is noted, and it also contains *Inoceramus Cuvieri* [? *mytiloides*]." He states that the succeeding beds are known as roadstone, because they supply flints for road mending, while the highest beds are only burnt for lime. *Terebratulina gracilis* [? var. *lata*] and *Galerites subrotundus* occur in the middle beds.

Mr. W. Hill has recently (1899) visited Hessle, and kindly sends me the following notes:—The continuous layer of flint near the top of the Hessle quarry is seen again at Hearfield's quarry about 200 yards north of the bridge over the line, and is known by the workmen as the "red bed." This pit is very deep, and its sides are absolutely perpendicular, so that it is like a huge square well. About 150 yards north of that worked by Hearfields Bros. is a new pit, at a rather higher level, which exposed the following section:—

	ft.	in.
Soil and rubble	3	0
Rather broken blocky chalk, hard and white with a layer of flint nodules	4	0
A well marked layer of marl	0	2
Massive chalk in two courses each with a layer of grey flints	4	6
A well marked seam of marl	0	3
Massive hard white chalk, in two courses, a layer of large flints near the base	7	6
Very veiny chalk, the veins strongly marked in dark grey marl	1	3
Massive chalk	5	0
	25	8

All the flints are of rounded nodular shapes, not mammillated or lenticular, and there are no continuous seams or floors. No fossils were found on the spot, but the character of the chalk suggests that it is a continuation of the *Terebratulina* zone, and Mr. Hill found fragments of several specimens of *Terebratulina* preserved in oxide of iron after treating a sample of chalk from this quarry with acid.

The next good section is in the cuttings on the Hull and Barnsley Railway by the east of South Cave. These also were revisited by Mr. Hill in 1899, and the following observations were made by him:—

"The lowest parts of the *Rhynchonella Cuvieri* zone are best seen near the western entrance to the short tunnel under Sugar Loaf Hill; this part is 13 feet thick, and consists of hard, rough, yellowish chalk without flints, divided into courses by thin seams of yellowish-grey marl. The courses are from a foot to eighteen inches thick, and the chalk weathers into flattish platy fragments; it contains *Inoceramus mytiloides*, and is succeeded by rough chalk with flints.

"The upper part of this zone is well exposed in the cutting between the second short tunnel and the long tunnel under Hill. Here the rough hard chalk, with layers of flint nodules, which appears to belong to the zone of *Rhynch. Cuvieri*, is continued, and its total thickness must be about 50 feet. Above this is from 20 to 25 feet of chalk with very few flints, and this is succeeded by firm white chalk, with well-marked layers of flint nodules about 10 feet apart. At the base of this last division are two courses of hard chalk, which weather out prominently; these may correspond with the chalky limestone seen at the top of the quarry near Hessle Station.

"This chalk, with layers of flints, is not accessible for measuring, but can be touched over the mouth of the tunnel, where I obtained several *Terebratulina gracilis*. Near the top of the cutting are two conspicuous layers of marl. No tabular or continuous flint is visible. The total thickness seen is from 130 to 150 feet."

The succession here appears to differ somewhat from that at Hessle, though there is a sufficient likeness between them to make it probable that both zones have continued to expand from Hessle northwards. Flints here make their appearance in the *Rh. Cuvieri* zone, and this appears to have a thickness of not less than 60 feet, while that of the *Terebratulina* zone, so far as it is exposed, may be put at between 70 and 80 feet.

Whether this part of the Chalk exhibits any further differences as it passes northward, or whether it continues to exhibit the facies seen in these cuttings we are unable to say, for no one has published any sufficient information about the inland exposures of these beds. The Rev. J. F. Blake says they can be seen at many places along the course of the Wolds, but also expressly states that he could not distinguish a zone of *Terebratulina gracilis* (op. cit., p. 262).

Mr. Hill has recently (1899) found a good section of the *Rh. Cuvieri* zone in a quarry at Goodmanham, near Market Weighton, the bottom being probably very near to the junction with Lower Chalk. The beds seen are as follows:—

	ft.	in.
Blocky chalk much broken into angular fragments, with layers of grey flint nodules - - - from 10 to	12	0
Buff coloured marly chalk, including lenticular layers of harder chalk - - - - - - - - - - -	0	8
Hard whitish chalk full of fragments of *Inoceramus* shell -	2	3
Layer of marl - - - - - - - - - - -	0	3
Hard rough nodular chalk, *Rhynchonella Cuvieri* - -	1	9
Thin layer of marl - - - - - - - -	0	2
Course of smoother chalk, hard and white - - - -	1	0
Thin layer of marl - - - - - - - - -	0	1
Massive course of rough nodular chalk, containing *Inoceramus mytiloides* and *Rh. Cuvieri* - - -	3	3
Layer of yellowish grey marl - - - - - - -	0	6
Smooth hard white chalk - - - - - seen for	2	0
About	24	0

Mr. Hill has also recorded a section through the base of this zone in a pit about a mile south-east of Londesborough;* this, with the wording slightly altered, reads as follows:—

		ft.	in.
Zone of *Rhynch. Cuvieri.*	Soil and rubble - - - - - - - -	1	6
	Hard whitish platy chalk, in rather thin beds, with some flints - - - - - - - -	3	0
	Creamy white chalk, in thick massive beds, divided by thin seams of marl - - - - - -	6	6
	Hardish smooth white chalk, from 10 inches to	1	0
	A marked layer of marl - - - - -	0	3
	Hard smooth creamy chalk - - - - - -	2	0
Belemnite Marls.	Softer marly chalk of creamy yellow tint - -	1	6
	Grey shaly marl, darkest in the centre - - -	1	6

Mr. Fox-Strangways mentions a quarry "between the two valleys at Londesborough," where the junction of the chalk without flints and that with flints is exposed, "the line being marked by a peculiar band which weathers in vertical lines, giving the bed a columnar aspect." He identifies this band with that which occurs at the base of the flinty chalk in Lincolnshire, a view which suggests a recurrence to the condensed Lincolnshire type, but one which requires confirmation in the light of subsequent observations.

The whole of the Middle Chalk comes into the cliffs east of Speeton Gap, but very little of it is accessible. Mr. Hill has given the following description of its base where it is first accessible, near the place known as Nanny Goats House†:—

	ft.
Hard white chalk with flints.	
Whitish bedded chalk, very hard and crystalline, with *Inoceramus mytiloides* - - - - - - - - -	5
Courses of creamy white chalk, about 6 inches thick, divided by buff-coloured marl-bands - - - - - -	2½
Lower Chalk (see p. 234.)	

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*Quart. Journ. Geol. Soc., Vol. xliv. p. 346, 1888. † Op. Cit. p. 345.

Where these beds come down to level of high-water-mark, they seem to have been crushed, and present a different aspect, which has been described by Mr. Fox-Strangways, from whose memoir the accompanying sketch is taken.* He states that the under surface of the Middle Chalk (bed *d*) is sharply defined, and is scored with slickensides.

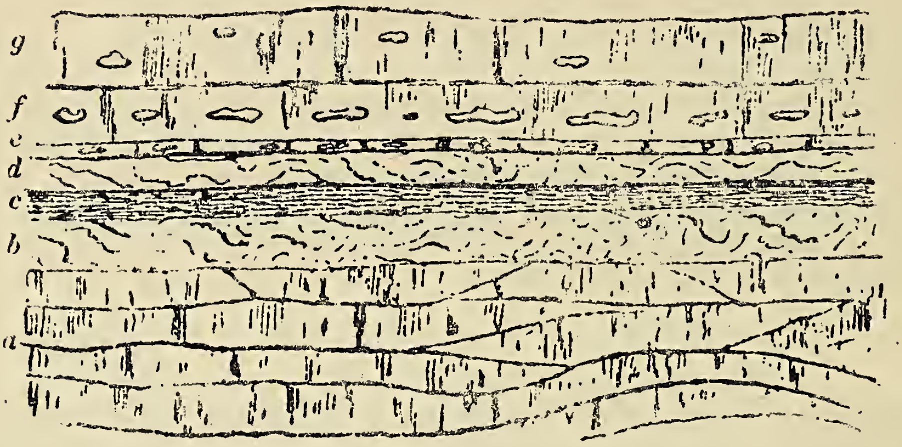

Fig. 84.—Junction of Lower and Middle Chalk in Buckton Cliff.

f. g. Chalk with flints in regular beds.
e. Thin bed of chalk with flints.
d. Very hard chalk, crushed and striated on the under surface; full of chalcedony.
c. Band of dark coaly shale.
b. Chalk much crushed, with veins of chalcedony.
a. Chalk without flints, irregularly bedded.

Fossils are not abundant in the Middle Chalk of Yorkshire, with the exception of *Inocerami*, which are common throughout, and the list of recorded species is rather longer than that for Lincolnshire. The following are all the occurrences that I can be sure of in the several zones :—

——	Zone of Rh. Cuvieri.	Zone of Ter. gracilis.
Ptychodus mammillaris, *Ag.*	x	–
Inoceramus Brongniarti, *Sow.*	–	x
,, Cuvieri, *Sow.*	–	x
,, mytiloides, *Sow.*	x	?
† ,, undulatus, *Mant.*	–	x
Ostrea vesicularis, *Lam.*	–	x
† Spondylus fimbriatus, *Goldf*	–	x
Rhynchonella Cuvieri, *d'Orb.*	x	x
Terebratula semiglobosa, *Sow.*	x	x
Terebratulina gracilis, var. lata, *Eth.*	–	x
Bourgueticrinus ellipticus, *Miller*	–	x
Galerites subrotundus, *Mant.*	–	x
Holaster planus, *Mant.*	–	x
† Salenia granulosa, *Forbes*	–	

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* Geology of the Country around Driffield, Mem. Geol. Surv., 1886, p. 10.

† Inserted on the authority of the Rev. J. F. Blake.

CHAPTER XLII.

THE EQUIVALENTS OF THE MIDDLE CHALK IN THE NORTH OF FRANCE.

The Middle Chalk of England corresponds exactly with the Turonien of d'Orbigny and with the "craie marneuse" and the "craie à *Inoceramus labiatus*" of Hébert.

Hébert afterwards included in it the zone of *Belemnites plenus* and divided it into three parts or zones thus[*] :—

Upper Zone.—Marly chalk with *Rhynchonella Cuvieri*, *Holaster coravium*, and *Inoceramus Brongniarti*.
Middle zone.—Nodular chalk with *Ammonites nodosoides*, *Am. rusticus* and *Am. catinus*.
Lower Zone.—Argillaceous chalk with *Belemnites plenus*.

In 1871 he included the overlying chalk with *Holaster planus* in his Turonien[†], and subsequently Professor C. Barrois showed reason for excluding the zone of *Belemnites plenus*, and for dividing the "craie marneuse" of eastern France into two zones—that of *Inoceramus labiatus* (restricted), and that of *Terebratulina gracilis*, the latter being the equivalent of Hébert's upper zone.[‡]

More recently still, higher beds (the zones of *Micraster breviporus* and *Micraster cortestudinarium*) have been referred to the Turonian by Professor Barrois and other French geologists, so that their Turonian now includes much more than that of d'Orbigny, which did not comprise any beds containing *Echinocorys scutatus* and its varieties. Such beds he referred to the Senonian, and so did Hébert up to the year 1870.

It is clear, therefore, that the French equivalent of our Middle Chalk is the restricted Turonian of d'Orbigny, and we shall see that in the cliffs of Normandy this division has the Melbourn Rock at its base, and the Chalk Rock above it, exactly as in so many parts of England.

To give anything like a complete account of the Turonian Chalk of the Paris basin would be quite beyond the scope of this memoir, and it must suffice if we confine our notice to those regions in northern France where the chalk of this stage exhibits such lithological changes as seem to indicate the neighbourhood of land. These regions are, of course, at the extreme north-eastern and at the extreme western borders of the area which it occupies. For a description of the former region, we shall rely chiefly on the publications of Professor

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[*] See Comptes-rendus Acad. Sci., 1864 and 1866, and Bul. Soc. Géol. de France, Ser. 3, Tom. ii. p. 416.

[†] See Bull. Soc. Sciences de l'Yonne for 1876, p. 15.

[‡] Ann. Soc. Géol. du Nord, Vol. ii. p. 146.

Ch. Barrois, and for the western area on those of Messrs. Hébert, Lennier, and P. Bizet.

1. The North-east of France.

Near Calais and around the Boulonnais, the two zones which constitute the Middle Chalk present the same lithological facies, and contain the same assemblages of fossils as they do in the south-east of England. They are well exposed in the cliff at and east of Cap Blanc Nez, as shown in Fig. 85, which is based on a section drawn by Professor Barrois.* He describes the two divisions as follows:—

	feet.
Compact thick-bedded white chalk, with *Terebratulina gracilis*, *Echinoconus subrotundus*, *Spondylus spinosus*, *Inoceramus Brongniarti*, etc. Some flints in its higher part - - - - - - - - - -	120
Hard gritty nodular chalk, greenish or yellowish, containing many fragments of *Inocerami*, *Inoc. labiatus*, *Ammonites nodosoides*, *Am. rusticus*, *Rhynch. Cuvieri*, *Cardiaster pygmæus* - - -	66
	186

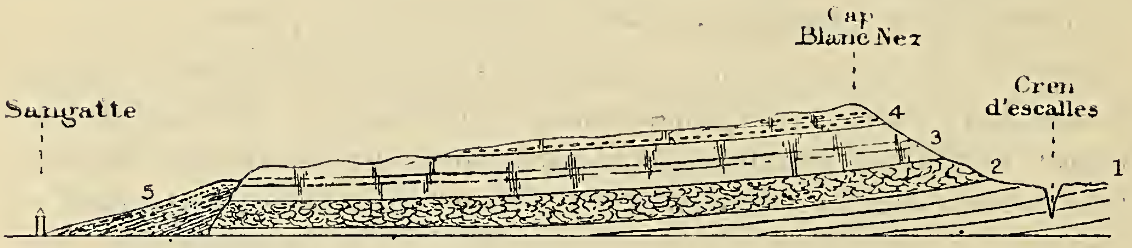

Fig. 85.—Section from Sangette to Cap Blanc Nez.
Horizontal scale 1 inch = 1 mile. Vertical scale 400 feet to 1 inch.

4. Zone of *Holaster planus*. 2. Zone of *Rhynch. Cuvieri*.
3. Zone of *Terebratulina gracilis*. 1. Lower Chalk.

Again in the southern part of the Paris Basin, in the departments of the Yonne and the Aube, they present similar characters, and have a combined thickness of from 350 to 400 feet.†

Between these two regions, however, there is another in which the beds gradually assume a different facies. Writing of the zone of *Inoceramus labiatus* Professor Barrois says:‡ "In the south of the department of la Marne this zone consists, as in the Aube, of hard nodular chalk containing Ammonites and the usual fauna. Towards the north it becomes more homogeneous, and I have only found Bivalves and Brachiopods in it. Still farther north, on the border of the department, it is still a hard chalk, but its thickness is reduced to a few inches. It is overlain and gradually replaced by an argillaceous marl, containing sometimes as much as 70 per cent. of clay, and dug for brickmaking. This argillaceous marl can be followed through the departments of the Ardennes, the Aisne, and the Nord, where the workmen give it the name of dièves. The stratigraphical relations of these dièves are most clearly seen in the Aisne and Nord, where they are divisible into a lower zone, very argillaceous, but poor in fossils, and an upper zone, less argillaceous, and containing an abundance of *Terebratulina gracilis.*"

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* Proc. Geol. Assoc., Vol. vi. p. 26 (1879).

† See Hébert (Bull. Soc. Sc. Yonne, 1876) and Barrois (Ann. Soc. Geol. Nord, T. ii. p. 146, 1875).

‡ Terrain Crétacé des Ardennes, Ann. Soc. Geol. Nord, T. v. p. 381 (1878).

"Not only are these zones distinguishable by their fossils and their lithological composition, but they are separated from one another by a bone-bed containing fish-teeth and phosphatised fossils rolled broken (at Foigny and Romery). The upper division represents the zone of *Ter. gracilis;* the lower division, lying between it and the marl with *Bel. plenus*, corresponds with the zone of *Inoc. labiatus.*"

In continuation he remarks that he had not previously been able to recognise the same sub-division of the dièves in the Ardennes, but that during a second exploration he had found fossils in the lower beds which included some special forms not found either in the beds above nor in the normal facies of the zone. Hence he concludes that these beds constitute a littoral facies of the zone, and that the nodular chalk was formed in deeper water.

These Turonian marls form the lower slopes of the hills which border the district of Champagne, and the following remarks (with Fig. 86) are quoted from Professor de Lapparent's well-known Manual of Geology (third edition, p. 1162):—"Near Valmy the zone of *Inoc. labiatus* is quite a marly chalk, and the zone of *Ter. gracilis* is a white marl of no great thickness, overlain by the nodular white chalk containing *Micraster breviporus* and *Holaster planus.*" Their respective thicknesses in this district are about 80 feet and about 20 feet.

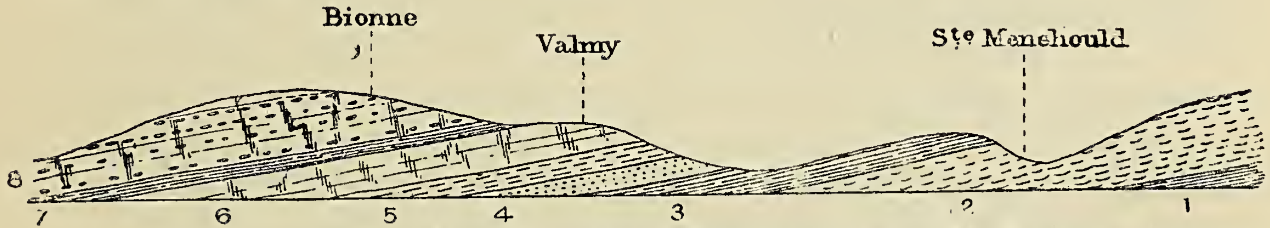

FIG. 86.—Section through eastern Champagne (after M. PERON).

8. Craie à Micrasters.
7. Marnes à Ter. gracilis.
6. Craie marneuse à I. labiatus.
5. Marnes cénomaniennes.
4. Glauconie à P. asper.
3. Marnes au dessus de la Gaize.
2. Gaize de l'Argonne.
1. Gault.

In the north of the Ardennes, near Coucy and Doux, Professor Barrois records exposures from which he obtained fossils, and from these it would appear that the thickness of the *I. labiatus* zone is there about 12 metres (40 feet), and that of the *T. gracilis* zone only about 3 metres (10 feet). Further north, near Vervins, the lower marls are over 60 feet thick, but the *T. gracilis* marl not more than 6 feet.

In the department of the Nord, these marls crop out in the valley of the Sambre, and in the Forest of Mormal, where their thickness is from 70 to 100 feet. To the north-west they have been identified in many of the deep borings, as at Valenciennes, Carvin, Guesnain, Orchies and Lille, with a thickness varying from 60 to 140 feet.

The following is a list of the fossils recorded by Professor Barrois from these two zones in the Dièves of Ardennes :—

——	Zone of Inoc. labiatus.	Zone of Ter. gracilis.
Otodus appendiculatus, *Ag.*	x	x
Ptychodus mammillaris, *Ag.*	x	x
Ammonites Bladenensis, *Schlüter*	x	—
,, Corneti, *Barr. et Gu.*	x	—
,, coucyana, *Barr.*	x	—
,, cf. hernensis, *Schlüter*	x	—
,, lewesiensis, *Mant.*	x	
Baculites bohemicus, *Fritsch*	x	—
Nautilus sublævigatus, *d'Orb.*	—	x
Cerithium sp.	x	—
Aporrhais [Rostellaria] cf. Buchi., *Goldf.*	x	—
Dentalium medium, *Sow.*	x	—
Natica cf. lamellosa, *Rœm.*	x	—
Pleurotomaria sp.	x	—
Pleurotoma Roemeri *Reuss.*	x	—
Rapa sp.	x	—
Scalaria abbreviata, *Bar. et Gu*	x	—
,, decorata, *Gein.*	x	—
Turritella multistriata, *Reuss*	x	—
,, sp.	—	x
Anomia semiglobosa, *Gein*	x	—
Astarte acuta, *Reuss*	x	—
Eriphyla lenticularis (?) *Goldf*	x	—
Inoceramus Brongniarti, *Sow.*	—	x
,, labiatus, *Brongn.*	x	—
Lima obsoleta, *Duj.*	—	x
,, semisulcata, *Nilss.*	—	x
,, sp.	—	x
Nucula semilunaris, *Reuss*	x	—
Ostrea canaliculata, *Sow.* (=O. lateralis)	x	x
,, auricularis, *Wahl.*	x	—
,, hippopodium, *d'Orb.*	x	x
,, vesicularis, *Lam.*	x	—
,, ungulata, *Coq.*	x	—
Plicatula Barroisi, *Peron* (as nodosa, *Duj*)	x	x
,, sigillina, *Woodw.*	—	x
Spondylus latus, *Sow.*	x	—
,, lineatus, *Goldf.*	x	—
,, spinosus, *Sow.*	—	x
Magas Geinitzi, *Schloenb.*	x	—
Rhynchonella Cuvieri, *d'Orb.*	x	—
Terebratula semiglobosa, *Sow.*	x	x
Terebratulina gracilis, *Schloth.*	x	x
,, striata, *Wahl.*	x	x
Bourgeticrinus ellipticus, *Miller*	x	x
Cidaris subvesiculosa, *d'Orb.*	—	x
Micrabacia sp.	x	—
Parasmilia sp.	x	—
Polyphragma cribrosum, *Reuss*	x	—
Flabellina elliptica, *Nilss.*	x	—

B. The North-West of France.

Passing across the central part of the Paris basin, which was part also of the central area of deposition, we shall notice some of the more western exposures of the Turonian Chalk. Excellent sections of this division are exhibited in the cliffs at Dieppe, Fécamp, and Etrètat, and these have been described by E. Hébert between the years 1872 and 1876, but so far as I can learn no more recent study of them has been published. There are also good exposures at Rouen, Villéquier, and other places in the valley of the Seine, which have been described by Monsieur G. Lennier and others.

The following general account of the "craie marneuse" in the Department of the Seine Inférieur is translated from the legend of the Yvetot sheet of the Carte Géologique Détaillée. "The highest part consists of white marly chalk, firm and without flints, characterised by *Terebratulina gracilis*. Below come beds which are not quite so white, containing many layers of black flints, and characterised by *Echinoconus subrotundus*. At the base are beds of much harder chalk containing *Inoceramus labiatus* (=*mytiloides*), which never contain flints, and are employed for making lime." From this it will be seen that the succession in this district corresponds very closely with that of Southern England.

I cannot find, however, that much information has yet been published about the country round Evreux and along the valley of the Eure, while on the higher ground of the Department of the Eure the chalk is concealed beneath some thickness of Tertiaries and of "clay with flints." When the Turonian emerges again in the Departments of the Orne, Eure et Loire, and Sarthe it exhibits a very different facies, and for these areas we have descriptions by the late M. Guillier, by MM. P. Bizet and A. de Grossouvre.

At Rouen the Turonian zones of *Inoceramus labiatus* and *Terebratulina gracilis* are said to be about sixty metres (about 200 feet); and more than half of this thickness is shown in the large quarries at the base of Mont St. Catharine. The following is an abbreviated account of this section, as given by Mr. Lennier.*

		Metres.
Zone of *Ter. gracilis.* 77 feet.	Weathered chalk	3
	Soft white chalk, with a few flints, *Ter. gracilis*	12
	Soft white chalk, with more numerous flints	8·50
	Layer of nodules of hard chalk, green-coated, and called "caillasse" by the workmen	·10

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*Bull. Soc. Geol. Norm., Vol. vi. p. 387.

		Metres.
Zone of *Inoceramus labiatus.* About 54 feet.	Hard and heavy limestone, perforated with tabules, many *Echinoconus subrotundus*, and *Ter. semiglobosa* - - - - - - - - -	·50
	Greyish marly chalk, with *Ech. subrotundus*, *Inoc. labiatus*, *Rhynch. Cuvieri*, etc.; flints rare -	6·00
	Soft white marly chalk, alternating with beds of hard greyish compact chalk - - - -	1·85
	Greyish marly chalk, with *Ammonites nodosoides* and large *Inoc. labiatus* - - - - -	2·50
	Greyish marly chalk, with some white nodules, *Am. catinus*, *Inoc. labiatus*, and fish remains -	3·50
	Thin continuous seam of flint - - -	·02
	Hard compact chalk, becoming nodular, and passing down into a hard and heavy nodular chalk, *Inoceramus labiatus* and *Cidaris hirudo* - -	2
		39·97

The hard nodular rock at the base is evidently comparable with our Melbourn Rock, and it rests on the grey marly chalk identified by M. Bucaille as the zone of *Belemnites plenus*. M. Lennier, however, does not separate the zone of *Ter. gracilis*, as at that time it was included in the zone of *Inoc. labiatus*; and I am responsible for the grouping above suggested. The zone of *Holaster planus* is exposed in another quarry near the top of the hill, and there is supposed to be a depth of twenty to thirty metres between the two sections, this being occupied by the rest of the *Terebratulina* zone. If this is correct, the total thickness of the Turonian here will be over 200 feet.

At Villéquier, lower down the Seine, the thickness of these beds is much reduced, and is said not to be more than twenty-five or thirty metres (less than 100 feet), but possibly the whole depth is not exposed, for their thickness at Fécamp on the coast to the north-west is given by Hébert as 45 metres,* and he divides it into two portions, a lower portion comprising the hard beds with *Echinoconus subrotundus* (9 metres), and an upper portion, in which *Rhynchonella Cuvieri* and *Spondylus spinosus* are abundant (36 metres). Here therefore the two zones have a combined thickness of nearly 150 feet. They can be followed westward in the cliffs as far as Etretat, where the beds are broken by faults, but appear to be at least 30 metres thick; thence they can be traced to St. Jouin, where the lower zone crops out at the top of the cliff. Here the thickness of the Turonian is given as only 12 metres. but probably this only refers to the portion which is visible, all the higher part having been removed by detritive agencies.

The country to the south-west of Rouen has not yet been much explored by French geologists, and the surface of the chalk is for the most part covered by a thick mantle of Clay-with-flints, so that it is only in the valleys that exposures of chalk are found. In the Orne, however, near la Ferte Fresnel and l'Aigle, the lower part of the Turonian is exposed in many places, and the marly chalk is quarried for the manufacture of cement. M. Bizet describes the succession as follows:—*

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*Bull. Soc. Geol. de France, Ser. 3, Tom iii. p. 519.

1. Chalk with *Terebratella Bourgeoisi* (seen near Nogent le Rotrou).
2. Marly chalk with *Rhynchonella Cuvieri* and *Inoceramus labiatus*.
3. Glauconitic chalk, with *Terebratella carantonensis* and *Ditrupa deformis*.

The lowest bed may possibly represent the zone of *Actinocamax plenus*, and it certainly recalls the sandy glauconitic chalk which contains that fossil and occupies a similar position on the coast of Devon; its thickness is only a metre (about 3 feet).

The zone of *Inoceramus labiatus* is described as a white marly chalk, more or less compact, with some layers of black flints, but containing very few fossils except the two above mentioned and *Ostrea columba*; its entire thickness may be about 30 feet. This marl makes good cement, and M. Bizet gives analyses of three samples from different places, as below:—

Analyses of "Craie marneuse."

	L'Aigle.	Irai.	Senouche.
Residue insoluble in acids	14·70	14·90	16·35
Alumina and peroxide of iron	·80	·85	·80
Lime	43·50	36·65	43·25
Magnesia	·50	·45	·25
Loss [carbonic acid], etc.	40·50	47·15	39·35
	100·00	100·00	100·00

Another sample from Remalard, east of Bellême, was still more argillaceous, yielding 26·25 per cent. of insoluble residue, with 6·30 of alumina and oxide of iron, and with only 32·45 of lime. This sample cannot therefore have more than 57 per cent. of calcium carbonate, while the others have probably from 65 to 70 per cent. This change from the calcareous facies of Rouen and Fécamp to a deposit resembling our chalk marl is very noteworthy.

One of the most westerly exposures of this marl is on the road from Verneuil to Alençon, showing:—

		feet.
Marly chalk, with *Inoceramus labiatus*		16
Yellowish marly chalk		1
Glauconitic marl, with *Ditrupa deformis*		3
Sands of the Upper Cenomanian	seen for	16

In the Sarthe, according to Guillier,† the basement bed of the Turonian is a quartz-sand, more or less coarse, sometimes compacted into sandstone by a calcareous cement. This sand varies in thickness from 3 to 30 feet, and is characterised by *Ostrea columba*, *Catopygus obtusus*, *Nucleolites parallelus*, and *Rhynchonella Cuvieri*. This is succeeded by a glauconitic chalk about 6 feet thick, containing *Terebratella carantonensis*, *Terebratula phaseolina*, and small oysters. The glauconitic chalk passes up into the white marly chalk of the zone of *Inoceramus labiatus*, which contains a few scattered flints and many concretions of iron pyrites, but is nowhere more than 30 feet thick in this district. Analyses given by M. Guillier show that it varies considerably in lithological composition, some samples containing 85 per cent. of calcium carbonate, others only from 66 to 74, with 24 to 28 per cent. of insoluble siliceous matter.

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* Bull. Soc. Geol. Norm., Vol. ii. p. 74.

† Géologie du department de la Sarthe, 1886, p. 266.

The *I. labiatus* marls are succeeded by beds which were described by Guillier as the chalk with *Terebratella Bourgeoisi*, but this has recently been separated into two zones by M. de Grossouvre,* a lower zone of yellowish sandy chalk or *tuffeau*, which contains many species of *Ammonites*, especially *peramplus*, *Woolgari*, *deverioides*, and *Galliennei*. This is generally 6 or 7 feet thick, and is well exposed at Poncé, Mézières-sur-Ballon, and Bourré, M. de Grossouvre regards it as equivalent to the zone of *Ter. gracilis*. The succeeding beds are still more sandy and micaceous and some of them contain concretions of granular sandy chert enclosing sponge remains; Bryozoa also are numerous, and among other fossils may be mentioned *Terebratella Bourgeoisi*, *Micraster Michelini*, *Ostrea turonensis*, and *Cyprina Noueliana*. These beds vary much in thickness, but are sometimes as much as 30 or 40 feet, and are regarded by M. de Grossouvre as the equivalent of the eastern zone of *Micraster breviporus*, and the *craie de Vervins*.

It would appear therefore that in the Departments of the Orne and the Sarthe, the Turonian is much thinner than it is to the eastward, and that it consists of the following beds:—

Yellowish sandy chalk, with *Am. peramplus* - -	6
White marly chalk, with *Inoc. mytiloides* - -	30
Glauconitic chalk, with *Ter. carantonensis* - -	6
Sand and sandstone (in Sarthe only) - - -	3 to 30
	45 to 70

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*Bull. Soc. Géol. de France, Ser. 3, Tom. xvii. p. 505, et seq.

CHAPTER XLIII.

THE MICROSCOPIC STRUCTURE OF THE MIDDLE CHALK.

By W. Hill.

The Middle Chalk, while showing some differences of character when considered in vertical section, shows little change laterally over the whole area included in this memoir. It will, therefore, be unnecessary to describe its aspect in different districts, except to notice some local peculiarity. Its basement bed is a hard white or yellowish-white rough nodular chalk, known as the Melbourn Rock. Above this bed the chalk becomes less nodular and more regularly bedded, though in some localities layers of nodules continue to occur for 40 or 50 feet, or even more. Many shell-fragments can be seen in it, and its weathered surfaces have a somewhat gritty touch. As one passes to the *Terebratulina* zone the chalk gradually assumes the character of a soft white pulverulent limestone, a condition which generally continues to the Chalk Rock, though sometimes in the South of England it becomes harder and more nodular again towards the upper part of the zone.

The Zone of Rhynchonella Cuvieri.

A. Melbourn Rock and Basement Beds.

Macroscopic Aspect.

The appearance of the Melbourn Rock is usually that of a hard white or yellowish-white rough nodular chalk, markedly seamed and veined by greenish-grey. Smoothed hand specimens show that the veins often define more or less clearly nodules or lumps of chalk of varying size, which are not infrequently coated thinly with a reddish-brown deposit. The nodules are in some cases thickly packed together in beds or layers, in others they are widely separated and distinct from each other, and sometimes spaces of comparatively smooth chalk separate well-marked nodular beds, but though the rock may appear to be smooth and without nodules, it invariably splits on weathering with a rough lumpy nodular fracture. There is great variation in the sharpness of the outline of the nodules. Sometimes they are seen as angular or sub-angular fragments of chalk, very clearly defined from the surrounding shelly matrix, and from this there is every gradation to those whose form blends with and is hardly distinguishable from the surrounding chalk. In size they vary from a minute fragment not larger than a pin's head, but whose outline is clearly defined in the surrounding material, to a rounded lump, as large as a fair-sized apple.

Though the Melbourn Rock forms the basement-bed over the area occupied by Middle Chalk, it ceases to hold this position in South and West Dorset, where more or less of it is replaced by a bed or beds of hard smooth chalk destitute of the nodules which are so characteristic of the Melbourn Rock, In Devon, the basel-bed is a hard, rough yellowish limestone, which differs both from the Melbourn Rock and the smooth chalk of Dorset.

Microscopic Aspect.

Examined under the microscope in thin sections the appearance presented by the Melbourn Rock is alike nearly everywhere, the chief differences being in the definition of the outline of the nodules and the varying proportions and size of the shell-fragments, Foraminifera, and " Spheres."

Before going further, a fuller reference must be made to the nature of the calcareous bodies which have been so often alluded to, and which are so important a constituent of many parts of the Lower and Middle Chalk. These Spheres are small bodies with either a perfectly spherical or slightly ovoid outline. They appear to be simple monothalamous cells, with comparatively stout walls, the material of which is now finely granular crystalline calcite. In both varieties the centre of the cell, though often hollow, is frequently filled with minute calcitic crystals. In size the Spheres are usually from ·06 to ·08 mm. in diameter, a few of the largest reaching ·1 mm., rarely more. The ovoid forms are rather smaller than the average-sized Sphere.

A great deal of doubt still exists as to the actual nature of these bodies. Early geologists referred to them generally as " the young of *Globigerina* or other Foraminifera," but if this was really the case in the many thousands present in the chalk, it would surely be possible to follow the Sphere to its adult stage. No such progress can be seen towards the fully developed *Globigerina* or any other Foraminifera, and, whatever their real nature may be, they certainly appear to have reached maturity.

Professor Blake, in his paper on the Yorkshire Chalk,* mentions the occurrence of minute hollow Spheres. He was " not able definitely to find any apertures in them ; otherwise they look like *Orbulina universa*, abounding to the exclusion of all other Foraminifera."

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*Proc. Geol. Assoc., Vol. v., p. 266 (1878).

In notes on the white chalk of Yorkshire, by Major-General Emmett,* Messrs. Parker and Jones suggest that these minute chambers were "separate cells of *Globigerina* and *Dentalina*, the former predominating."

M. Cayeux, who has also noted their extreme abundance in the chalk, particularly at the base of the Turonian, in many localities in the Paris basin, refers to them as monolocular Foraminifera† of the genus *Fissurina* or *Orbulina*. In the zone of *Inoceramus labiatus* near Rouen, he estimates the Spheres to form 95 to 98 per cent. of all the *Rhizopodal fauna* (pages 288 and 305).

In 1890 Dr. Hinde wrote: "I do not think they can be placed with *Radiolaria*, and they are not to be included with sponges."‡

Mr. F. Chapman, who also kindly examined some of our washings containing Spheres, believed some of them to be Radiolaria, and thought that in some instances he could make out a "medullary cell" and its supports, and see also traces of the siliceous network of the walls. In other more flattened sphæroids, he saw a strong resemblance to the globate dermal spicules of certain sponges; but the real nature of the majority of these calcareous spheres still remains an enigma.

Besides the Spheres, there occur in most chalks many "cells" which, without doubt, are the young of Foraminifera, and are not infrequently double. Though single cells can easily be confounded with true Spheres, they may usually be recognised by their thinner walls and by some irregularity of outline. Such cells are more easily recognised in the Upper Chalk, where they sometimes form the most prominent feature in thin sections, and where Spheres are less abundant.

In all specimens examined from Dorsetshire the nodules are ill-defined, and the rock consists chiefly of spheres thickly packed in a calcareous paste, now indurated by semi-crystalline granular calcite, while here and there large *Globigerina* and a few *Textularia* occur. Large, coarse shell-fragments are not common, but the matrix of several specimens is full of minute calcitic particles probably derived from shells.

Specimens of Melbourn Rock from Wiltshire and from all counties to the north-eastward, including Suffolk and Norfolk, and those also from the south-eastern counties including Hampshire and the Isle of Wight, all present much the same general characters.

The leading feature in all cases is the abundance of shell-fragments, either fine or coarse, and of Spheres. The shell-fragments are chiefly prisms of *Inoceramus*, or fragments of these shells showing the prismatic structure. The quantity of shell-particles seen in different specimens varies considerably. In some cases they form 60 per cent. of the rock-material, or even more, and where shell-fragments are a less important constituent, large and coarse prisms or pieces of *Inoceramus* shell are often a marked feature in thin sections of the rock. The interstices between the shell-fragments are often crowded with Spheres, and where shell-fragments are not abundant the Spheres frequently constitute the major part of the deposit, while here and there a large *Globigerina* or *Textularia* occurs.

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*Geologist, Vol. iii., p. 420, 1860.

†Contribution à l'Etude Micrographique des Terrains Sedimentaires, pp. 222, 263, 267, 401, etc.

‡Journ. Roy. Mic. Soc., 1890.

In the counties of Buckingham, Bedford, Hertford, and Cambridge the Melbourn Rock consists of two well-defined layers—a lower nodular bed, white in colour, and an upper yellowish layer. In the lower layer (Plate VII. Fig. 1) the nodules are thickly packed, sometimes well defined, but sometimes difficult to distinguish. Under the microscope they are seen to consist of more evenly constituted chalk than the surrounding matrix, and frequently contain traces of *Radiolaria*. The matrix usually consists of amorphous material and fine calcareous particles, but occasionally large fragments of *Inoceramus* shell occur, while Spheres are abundant, and form a large part of the rock. The upper yellower part (Fig. 2) is smoother, the nodules often widely separated and better defined than in the lower layer. Coarse fragments of *Inoceramus*-shell are a feature in the amorphous matrix, and Spheres are not so important a constituent of the deposit.

In specimens from well-marked nodular rock it will be seen that the nodules have a different structure to the surrounding chalk. They consist of a fine, somewhat dense calcareous paste, now hardened by the infiltration of calcite ; Spheres are moderately abundant, and a few *Globigerina* and *Textularia* can be seen, but shell-fragments are not numerous (see Plate VI.). As a rule they resemble the upper part of the Lower Chalk and the hard white chalk which often occurs in the Belemnite Marls.

The material surrounding the well-marked nodule is usually crowded with coarse shell-fragments ; a few *Globigerinæ* occur, while "Spheres" often occupy all the other available space, the whole being cemented by amorphous calcareous paste, now finely granular crystalline calcite. In some cases where the whole of the amorphous paste is removed, the matrix is practically a shell sand, and the cementing material is infiltrated calcite (Plate VI. Fig. 1). The difference in the character of the nodule and that of the surrounding matrix is often striking, and in many examples of this rock a distinct arrangement of the particles of shell can be traced round the nodule, strongly suggesting that they had been deflected from their course by the nodule while travelling over the sea-bed under the influence of a gentle current.* From the well-marked nodule there is every gradation to one the boundaries of which cannot be distinguished from the surrounding matrix in a thin section, but which, on the other hand, may be detected in a smoothed hand specimen of the rock.

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* The nodular character of the Melbourn Rock is often very well shown in rolled fragments on the sea-shore, as near Dover and Beachy Head.

Nodules are least distinguishable from the mass of the Melbourn Rock where but few shell-fragments are present and the matrix has a finer grain approximating more closely in its character to that of the nodule. In such cases the presence of *Radiolaria* will sometime serve to distinguish nodule from matrix, for it is only in the nodules of the Melbourn Rock that well-marked traces of *Radiolaria* occur. Bodies of peculiar aspect, but otherwise somewhat inconspicuous, were noticed many years ago, but it was not until the changes in the mineralization and structure which the *Radiolarian* test undergoes had been studied in the rocks of Barbados that their true origin became manifest. *Radiolarian* have been noticed in the nodules of the Melbourn Rock from many localities.* Their siliceous skeleton has entirely disappeared, and the whole form is filled in and replaced by calcite. It is therefore impossible to refer the forms to their respective genera with accuracy, but they appear to belong to the sub-class *Spumellaria,* and to the families *Liosphœrida, Astrosphœrida,* and *Staurosphœrida,* and some to the genera *Dorysphœra* and *Amphibrachium.*

Specimens of the basal beds of the Middle Chalk from Lincolnshire and Speeton resemble more closely those from Dorsetshire than those from the intermediate counties, the nodules being ill-defined. The rock is often very full of coarse shell-fragments, while in other cases Spheres constitute the chief recognisable ingredient.

Washings.

From the hard, rocky nature of the chalk at this horizon, washing the specimens would be of little use, unless time allowed the examination of a large quantity of material. It was, therefore, not attempted.

Examination of Residues.

Eight specimens of the Melbourn Rock have been chemically treated either by myself or by Dr. Hume, and it will be seen from the results given in the table that there is a general uniformity in the series, and that the amount of residue obtained from any one of them is comparatively small. The largest amount was obtained by Dr. Hume from the "grit-bed" of Dover, while that of north-west Norfolk is the purest chalk, containing scarcely 1 per cent. of residuary matter.

Detrital Minerals.—The quantity of detrital minerals in the Melbourn Rock is very small. Quartz is the most abundant; it occurs as usual in minute angular and subangular or rounded grains. Besides quartz, Mr. Teall recognises orthoclase in the coarse residue of the specimen from Barret Ringstead, Norfolk, and three grains of magnetite adhered to the magnet on its application to the residue of the same specimen.

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* Quart. Journ. Geol. Soc., Vol. li., p. 600. (1895.)

From the base of the nodular chalk at Swanage Dr. Hume records felspars "which differ but little from the quartzes by which they are surrounded; they are, however, at once distinguished by the kaolinisation which they have undergone." He also notes that at Folkestone zircons occur so large and conspicuous as to attract attention on mere inspection of the residue, and not only in rounded grains but fragments of well preserved crystals.*

The average size of detrital minerals in our residues varies from ·10 mm. to ·19 mm., the largest grains measuring ·53 and ·48 mm., but Dr. Hume found grains measuring 2½ mm. by 1¼ mm. at Swanage.†

Secondary Minerals.—Besides masses of a porous iron oxide of irregular shape, which occur in all the residues, there is little to record under this heading. Glauconite is rare and generally absent altogether, but in the rock at the base of this zone at Beer there are casts of Foraminifera in a yellowish glauconite.

In every residue from chalk at this horizon there occurred peculiar honeycomb-like structures, apparently of organic origin. Dr. Hume thus refers to them ‡:—"They appear perfectly snow white when viewed by reflected light, and looked at from the upper surface present a very definite network, the orifices being frequently circular in outline, and the walls complete and somewhat thickened. In transverse section the canals are tubular, and the walls are then sometimes seen to be themselves perforated by numerous apertures." Dr. Hinde examined these structures, but was unable to refer them to any sponge family. "The conclusion finally arrived at is that the networks were originally sponge-mesh, but that subsequent chalcedonic changes have obliterated all those characters which would enable their true generic position among the *Porifera* to be determined."

There are also other silicified fragments occurring in many of the specimens which Dr. Hume describes in his notes on the Middle Chalk of Devonshire:—"These consist of the silicified columnar aggregates formed interprismatically in *Inoceramus*-shell." A few silicified prisms of *Inoceramus*-shells also occur. Besides the fragments noted above there were a few flat pieces in some of the residues, probably shell, but showing no definite structure.

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* Chemical and Micro-Mineralogical Researches, p. 49.

† This observation requires confirmation; it is possible that the large quartz-grains may have been driven from the shore into the crannies of the rock from which the sample was taken, or that some of the white chalcedonic lumps, which are from 2 to 3 mm. in size, were mistaken at the time for quartz.

‡ Chemical and Micro-Mineralogical Researches, p. 47.

A considerable portion of many of the residues consisted of small aggregations apparently of fine siliceous matter; these had no definite form, and did not appear to be fragments of *Foraminifera.*

Foraminifera.—Our remarks on the *Foraminifera* of the Melbourn Rock are confined exclusively to the forms isolated from the acid residues; doubtless if time allowed, and a sufficient number of specimens were broken up and examined, the list of forms would be materially increased. This list is as follows:—

—	Mupe Bay.	Swanage.	Dover.	Hitchin.	Ringstead, Hunstanton.	Louth, Lincs.	Speeton, Yorks.
Rhizammina	–	?	?	–	–	–	–
Reophax (sp. nov.)	–	–	–	–	x	–	–
Haplophragmium sp.	–	H	H	–	–	–	–
Ammodiscus incertus, *d'Orb.*	x	H	x	x	x	x	x
,, tenuis *Brady*	x	–	–	–	x	–	x
,, charoides *J. & P.*	–	–	x	x	x	–	–
Textularia minuta, *Berth*	–	H	–	–	–	–	–
Bulimina Presli *Reuss*	x	–	x	x	–	–	–
,, affinis, *d'Orb.*	–	–	–	–	–	–	–
,, brevis, *d'Orb.*	–	–	x	x	–	–	–

Those marked H are recorded in Chemical Micro-Mineralogical Researches, pp. 47 and 50; the remainder are from our own residues, and have been identified by Mr. F. Chapman.

It will be seen that the prevailing forms of this zone belong to the genus *Ammodiscus.* Bulimines occur sparingly; *Bulimina Presli* and *Bulimina brevis* continue into this zone, but the specimens are small and delicate. It may be noted that they still occur in southern specimens. All the forms in the above list range up from the Lower Chalk.

The tabulated results obtained from analyses of the Melbourn Rock will be found on p. 512.

B. CHALK ABOVE MELBOURN ROCK.

Microscopic Aspect.

With one exception there seems but little difference in the chalk of this zone; from whatever locality the specimen is taken the same general characters are exhibited when a thin section is viewed under the microscope.

This chalk is specially characterised by the abundance of Spheres, which seem larger and more boldly outlined than at any other horizon: their cell-walls are often well defined by a rim of clear crystalline calcite, and their interiors are filled with calcitic crystals, so that the contrast between them and the darker tint of the calcareous matrix, in which they are embedded, brings them into strong relief when thin sections of the rock are viewed under the microscope (see Plate VIII. Fig. 1). Large *Globigerina* and a few *Textularia* also occur, the former being fairly numerous in some specimens, but as a whole their proportion to the mass of the rock is not great. Large fragments of *Inoceramus*-shell are abundant, and serve also to distinguish this zone from all others in the chalk, but their number diminishes gradually towards the summit of the zone.

The regular character of this zone is, however, broken in Devonshire by the well-known Beer Freestone, and by other, but less important, rocky beds which occur above or below this stone. The Beer Freestone consists almost entirely of coarse calcareous shell-fragments. Some of these are prisms of *Inoceramus*, and others are plates of *Echinoderms*, but the larger number are fragments of irregular shape, which show a peculiar perforated or cellular-like structure. There are no Spheres and very few Foraminifera, but the interstices between the shell-fragments are filled with amorphous calcareous material, the whole being in a semi-crystalline condition. The rock is therefore a shell limestone, and can hardly be called a "chalk."

The basal part of the freestone has a similar structure, consisting almost entirely of perforated shell-fragments. Our section contains also three or four large glauconitic grains.

Since the above was written, Dr. G. J. Hinde has cut slides from samples of the Beer and Sutton freestones sent him by Mr. Jukes-Browne. These show that both freestones have the same constituents and a similar structure, but that Foraminifera are rather more abundant in the Sutton stone. Dr. Hinde writes: "From further study of the puzzling reticulate structure, I think that some at least may be due to the excavations of boring organisms in fragments of *Inoceramus*-shell. The borings do not remind me of those of boring sponges, but there are various organisms capable of this work."

Above the freestone is the "cockly" or "roof bed," as it is called by the workmen. This has a structure which recalls that of the Melbourn Rock. A thin section shows the rock to consist largely of coarse shell fragments, chiefly *Inoceramus*-prisms, and a few showing the cellular structure; large *Globigerina* are common. These coarse organic fragments are rather irregularly distributed, and in some places not very closely packed, the intervals being filled with amorphous calcareous paste, in which a good many spheres occur. The section contains also well-marked areas, which appear to be nodules of partly consolidated chalk of quite a different character. These nodules consist chiefly of amorphous paste, numerous spheres, and scarcely any shell fragments. Four or five large grains of glauconite occur in this section, and a single and somewhat large grain of quartz.

The hard limestone from the top of the *Cuvieri* zone in Beer quarries is a true chalk, consisting of a fine chalk-paste crowded with shell-fragments, Foraminifera and Spheres, the fragments being of Echmodermal plates and spines, and of Inoceramus and Bracluopod shells.

Examination of Residues.

The results of ten analyses of the Chalk of this zone are given in the annexed table, no less than seven of them being from notes by Dr. Hume. Five of these are from an exceedingly interesting locality, viz., Beer in Devonshire, and they include the well-known Beer Stone. (See p. 513.)

The amount of fine residue does not vary greatly, with the exception of the specimen from Eastbourne, which contains 7·72 per cent. of fine clay, an amount which exceeds that of many specimens at the summit of the zone of *Holaster subglobosus*. The next highest is that from the specimen from Beer, Devonshire, with 3·812 per cent. Those from Herts and Beds are much alike in character, while at Hessle we get for the first time a residue, of less than 1 per cent. The larger proportion of coarse residue, both in this and the Hitchin specimen, is accounted for by the occurrence of the small chalcedonic nodules.

Detrital Minerals. – These occur in greatest variety in the Devonshire specimens.

From the lower part of the zone at Beer Bay Dr. Hume identified Quartz, silvery white Muscovite and brown Biotite, and in the higher part of the zone Tourmaline is added to these.

In the Beer Stone Dr. Hume recognises amongst the detrital minerals Quartz, Rutile, Tourmaline, Andalusite and Anatase. From other localities Quartz and Zircon are the only two which have been identified.

The largest grains occur in the Beer Stone, one of them, slightly coloured yellow, having a diameter of ·88 mm. The next largest is from our own specimen from Lulworth, the maximum here being ·48 mm. The average size both at Beer and Lulworth is the same, viz., ·15 mm.

Secondary Minerals.—Glauconite was not found in any specimens from this zone, except in those from Devonshire. Deep green grains of glauconite are present in the Beer Stone. and small grains were scattered through the residue of an example from the bed which represents the Beer Stone in Beer cliffs.

Dr. Hume records limonite in short, stout rods, consisting of small brown pellets bound together and changed externally into yellow ochre in many places. Irregularly shaped masses of iron oxide were of common occurrence in the more easterly specimen.

We now give Dr. Hume's original notes on the analyses of specimens from this zone in Devonshire:—

"**Base of Rhynchonella Cuvieri zone** (eastern side of Beer Bay).—*Inoceramus mytiloides* and small *Discoidea* abundant in the rock. The residue, coarse enough for examination, weighed only ·054 gramme, and of this ·039 gramme consists of the silicified columnar aggregates formed interprismatically in *Inoceramus*-shells. Many of these viewed from above show an open hexagonal meshwork, and from the side an arrangement of delicate columns or films. Others, in which the change has proceeded further, are covered on the surface with rounded chalcedonic projections, the columns at the upper surface being expanded. In the finer residue a noticeable feature is the abundance of irregular or sub-hexagonal flakes of mica, showing very low tints from grey to almost black. These are mostly silvery-white Muscovite, though thin brown flakes of Biotite are also present. The remainder of the residue consists mainly of yellow glauconitic internal casts of *Foraminifera*, mostly in single spherical chambers, but not unfrequently also in aggregates of three or four, these combinations being not, however, sufficiently well preserved to determine the probable genus.

"The average size of the quartz grains is about ·15 mm. Compared with the beds below, there is thus a marked diminution in the quantity of detrital minerals, mica and quartz being the only representatives.

"**Middle Beds of Rhynchonella Cuvieri zone** (Pinhay Cliff, near Lyme Regis).—The amount of coarse residue in this sample weighed ·027 gramme, and of this ·017 gramme consisted of silicified *Inoceramus* fragments similar to those previously described—viz., hexagonal meshes or papery films. The remainder consists mainly of angular quartz grains, whose average size was ·125 mm. in diameter, and the largest does not exceed ·27 mm. Glauconite grains are scattered through the residue, but present no special features of interest. Flakes of Muscovite mica are not uncommon, but no heavy minerals were observed. The remainder of the residue consists of the silicified organic fragments previously referred to. Amongst the residue was a beautifully preserved small idiomorphic crystal of quartz, the prism and rhombohedral faces being well developed. It also contained a few rounded gas cavities.

"**Upper part of Rhynchonella Cuvieri Zone** (Pinhay Cliff).—The residue, in its main features, consists of the remains of silicified *Inocerami* and foraminiferal tests, numerous rod-like aggregated masses of Limonite, quartz grains, the largest 3 mm. diameter, and flakes of muscovite mica. ·011 gramme of the residue was over ·5 mm. diameter, and consisted almost entirely of silicified *Inoceramus* fragments, in which the original hexagonal mesh has become obscured owing to the stalactitic outgrowths of the chalcedony. The limonitic aggregates are, as already remarked, in short stout rods, consisting of small brown pellets loosely bound together, and changed externally into yellow ochre in many places. Several thin flakes of silvery muscovite mica are also present, showing feeble tints under crossed Nicols. In the finer residue the remains of silicified *Foraminifera* are very numerous, two specimens of *Ammodiscus incertus* being still recognisable, while the length and pyramidal form of some of the silicifications point to their having been tests of *Textulariæ* or *Bolivinæ* now altered beyond recognition. A few rounded grains of glauconite are present, one case also of a two-chambered cast united by a broad connection being observed.

"The quartz is mostly angular and colourless, only containing minute gas inclusions. Tourmalines have been noted, one a crystal, having perfect rhombohedral terminations at one end, but fractured at the other ; while another is an irregular brown grey fragment, showing very strong absorption.

"**Typical Beer Stone** (Mr. Jukes-Browne's specimen).—The residue of this weighed ·092 gramme and consists mainly of highly angular quartz, accompanied by numerous flakes of silvery muscovite mica, green grains (rounded chamber-casts) and rods of glauconite, these being comparatively rare, a little chalcedony, some pyrites, and abundant crystals of black, fibrous columnar tourmaline.

"The following is a more detailed account of the detrital minerals observed :—

"*Quartz Grains.*—Although, as has been stated, the residue consists in the main of fine angular particles, some twenty larger grains are also present, the largest of which, coloured slightly yellow, has a diameter of ·88 mm. The others were colourless, or else coloured of the same yellow tint. The larger grains contained rows of gas cavities.

"*Chalcedony.*—A bluish-coloured mass, showing the familiar stalactitic outgrowths, is the only evidence of this mineral.

"*Rutile* is present in orange flakes, of no definite form.

"*Tourmaline* is very abundant in the form of aggregated crystalline fibres of a blue-grey colour, recalling the tourmalines in Luxullianite. The absorption is very strong, the other characters being as usual.

"*Andalusite.*—One or two apparently colourless grains showed the delicate rose-pink to almost colourless pleochroism of this mineral, such as may, for example, be observed in many of the Andalusites of the Cornish granites.

"*Anatase.*—Deep blue irregular fragments are present, which probably are referable to this mineral, but this cannot be stated with certainty.

"*Glauconite* is present in deep-green rounded grains, evidently internal casts, but giving no clue to the organisms from which they were derived.

"*Muscovite* occurs in thin silvery-white flakes, polarizing in very low tints, while brown flakes of equal thinness must probably be referred to biotite.

"The residue from this rock is of particular interest in consequence of the presence of Andalusite and Fibrous Tourmaline, these not having been obtained from the residues in the Isle of Wight, Eastbourne, Folkestone, or the Midlands, and being well-known constituents of the granitic rocks in the south-western counties.

"**Beer Stone** (this example was collected by the writer from the Beer Quarries).—The material exceeding ·5 mm. only included a few silicified snow-white organic fragments and some rounded quartz grains.

"The rest consists of silicified Foraminifera of no definitely recognisable shapes, flakes of muscovite mica, numerous rods of glauconite, angular grains of quartz, and a few minute crystals (one of them perfectly terminated at both ends) of Tourmaline, and also one fragment of the columnar type previously mentioned."

W. F. Hume.

Examination of Washings.

Specimens of the chalk of this zone from Beer Head (Devon), Dover, and Hitchin were washed. That from Beer Head was hard and in a semi-crystalline condition, and the results were less satisfactory than in the case of the other two, but sufficient evidence was obtained to show that it differed but little from the others.

Shell-Fragments.—These were all of *Inoceramus*-shell. Many were large pieces showing the prismatic structure; the remainder were chiefly prisms. There were also a few ossicles of Starfish, and in the Dover specimen one or two Echinoderm plates and a few fragments of rather large spines occurred. No fish teeth, scales, or coprolites were observed, and no sponge-spicules.

The following is a list of the Foraminifera isolated during the examination of the washings and the acid residues, and named by Mr. F. Chapman :—

—	Beer, Devon.	Lulworth, Dorset.	Eastbourne, Sussex.	Dover, Kent.	Hitchin, Herts.	Hessle, Yorks.
Haplophragmium sp. nov.- - -	–	–	–	–	–	x
Ammodiscus incertus, *d'Orb.* sp. -	–	–	x	–	–	x
Trochammina sp. - - - - -	–	–	–	–	–	x
Textularia trochus, *d'Orb.* - -	x	–	–	–	–	–
„ turris, *d'Orb.* - - - -	–	–	–	x	x	–
Tritaxia tricarinata, *Reuss* - -	–	–	–	x	x	–
Gaudryina filiformis, *Berth.* - -	–	x	–	–	–	–
„ (?) species - - - - -	–	–	x	–	–	–
Bulimina affinis, *d'Orb.* - - -	–	x	–	–	x	–
„ brevis, *d'Orb.* - - -	–	x	–	–	x	–
„ (?) species - - - - - -	–	–	x	–	–	–
Cristellaria cultrata, *Montf.* sp. -	x	–	–	–	x	–
Globigerina marginata, *Reuss.* sp. -	x	–	–	x	x	–
Truncatulina ungeriana, *d'Orb.* sp. -	–	–	–	x	x	–
„ lobatula, *Walker* and *Jacob*, sp. - - -	–	–	–	–	x	–
„ akneriana, *d'Orb.* sp -	–	–	–	–	x	–
Anomalina ammonoides, *Reuss.* sp. -	x	–	–	–	x	–
Rotalia Soldani, *d'Orb.* sp. - -	–	–	–	x	–	–

This list is too short to make a satisfactory comparison. All our specimens of this zone, other than those experimented on, are hard and rocky. The Hitchin specimen was the softest, and, though a larger amount of this material was broken up and washed, the result was poor.

Ostracoda. —These organisms are not common in this zone; the only ones isolated, *Cytherella Munsteri* (Röm.) and *C. ovata*, occurred in the Hitchin specimen.

TABULATION OF RESULTS.—MELBOURN ROCK AND BASEMENT BEDS.

Number.	General Composition.							Composition of Coarse Residue.						Remarks.
	Locality.	Amount of Material.	Per cent. Soluble in Acid.	Per cent. Coarse Residue.	Per cent. Fine Residue.	Total per cent. Residue.	Colour.	Detrital Minerals.	Per cent.	Maximum size of Grains.	Average size of Grains.	Secondary Minerals.	Foraminifera.	
		gram's								mm	mm			
62	*Devonshire. Beer Bay, base of the zone.	79·23	96·12	·0684	3·812	3·880	—	Mica (Muscovite and Biotite), Quartz	—	—	·15	Glauconite -	—	Much of this residue consisted of silicified Inoceramus.
54.	Dorset (North). Cerne Abbas - -	81·199	96·76	·03	3·21	3·24	Grey -	About 20 grains of quartz	—	·38	·12	Small fragments of iron oxide	None - -	More than half the coarse residue consisted of chalcedonic honeycomb-like network and inter-prismatically silicified Inoceramus shell (see page 505). (Spheres abundant, shell-fragments common.)
55.	Dorset (South). Mupe Bay, Six feet above Bel. Marl	82·819	97·33	·06	2·60	2·66	Grey -	About 20 grains of quartz	—	·27	·11	A few minute fragments of iron oxide	Ammodiscus, Bulimina	Half the coarse residue consisted of chalcedonic network and Inoceramus shell. (Spheres abundant, shell-fragments common.)
56.	*Swanage, Base of nodular chalk -	81·98	97·65	·02	2·32	2·34	—	Quartz, felspar	—	2·3	—	Iron oxide -	Ammodiscus, Textularia, Haplophragmium	Much chalcedonic network.
57.	Kent. †Dover - - -	78·58	95·87	·01	4·12	4·13	—	Quartz, zircon	—	—	—	—	Bulimina, Haplophragmium	The quartz occurs in clear colourless grains, the zircons large and conspicuous.
58.	Herts. ‡Hitchin - -	80·59	97·45	·013	2·54	2·55	—	—	—	—	—	—	Ammodiscus, Bulimina	
59.	Norfolk. Barret Ringstead, Hunstanton	101·65	99·01	·008	·99	·99	Grey -	Quartz, magnetite	—	·53	·12	Iron oxide -	Reophax, Ammodiscus	About 20 per cent. of the coarse residue consisted of brownish aggregations of structureless siliceous matter. A few fragments of chalcedonic network, and a good many silicified Foraminifera. Red brown iron oxide present in small fragments. (Many coarse shell-fragments and Spheres.)
60.	Lincolnshire. Louth, Basal bed of Mid. Chalk	85·252	97·42	·03	2 55	2·58	Grey -	Quartz - -	—	·19	·10	Iron oxide -	Ammodiscus -	One large aggregation of fine siliceous material. Two or three small fragments of chalcedonic network; a fair number of Foraminifera.
61.	Yorkshire. Speeton - -	99·065	97·86	·03	2·11	2·14	Grey -	Quartz, about 20 grains	—	·48	·19	Iron oxide -	Ammodiscus -	The major part of this residue was brown iron oxide, and this material had replaced the walls of the network structure. Several small fragments of this occurred.

* Micro-Mineralogical Researches, page 46.

† Micro-Mineralogical Researches, page 68.

‡ From Notes by Dr. Hume.

TABULATION OF RESULTS.—ZONE OF RHYNCHONELLA CUVIERI.

Number.	Locality.	Amount of Material.	Per cent. Soluble in acid.	Per cent. of Coarse Residue.	Per cent. of Fine Residue.	Total per cent. Residue.	Composition of the Coarse Residue.						Remarks.
							Colour	Detrital Minerals.	Maximum size of grain.	Average size of grain.	Secondrry Minerals.	Foraminifera.	
		gr'ms.							mm.	mm			
63	*Devonshire. The middle of the zone.	80·01	95·64	·0337	4·324	4·358	—	Quartz, Mica	—	·12	Glauconite	—	Silicified *Inoceramus* prisms common.
64	The upper part of the zone	81·97	96·80	·0405	3·159	3·199	—	Quartz, Mica, Tourmaline	·30	—	Glauconite, Limonite	Ammodiscus. ? Textularia ? Bolivina	The limonite aggregates in short stout rods consisting of short brown pellets loosely bound together. The residue consisted largely of silicified *Inoceramus.*
65	Beer. Stone, No 1.	81·71	96·55	·1126	3·341	3·454	—	Quartz, Tourmaline, Andalusite, Anatase, Mica (muscovite)	·88	—	Glauconite (rare). Pyrites (rare)	—	The glauconite chiefly in rod-like lengths.
66	Beer Stone, No. 2	83·00	98·23	·0251	1·751	1·775	—	Quartz, Mica (muscovite), Tourmaline	—	—	Glauconite	—	Rods of glauconite numerous.
67	South Dorset. Lulworth, about 45ft. above the zone of Belemnitella plena	88·719	97·72	·05	2·23	2·28	—	Quartz	·48	·15	Iron oxide	Gaudryina Bulimina	The coarse residue was chiefly mineral grains with a few fragments of iron oxide, Chalcedonic network, and silicified *Inoceramus* was also present, but not abundant, both were occasionally encrusted by limonite. (Spheres 75 per cent., very few other Foraminifera or shell fragments.)
68	† Sussex. Eastbourne	44·94	92·28	·004	7·72	7·724	—	Quartz, Zircon	—	—	—	Ammodiscus, Gaudryina, Textularia	This residue consists of small angular fragments of quartz and small grains of limonite, and a number of delicate Foraminifera ; only one zircon present.
69	†Bedfordshire. Dunstable	80·04	98·28	·01	1·71	1·72	—	Quartz	—	—	—	—	This residue contained silicified portions of Inocerami large grains of quartz, and pieces of limonite.
70	Herts. Hitchin Station, 35ft. abov the Belemnitella marls	78·876	98·16	·19	1·65	1·84	Grey	Quartz	·18	·14	—	Ammodiscus	About 70 per cent. of this residue consisted of white mesh works and silicified *Inoceramus* prisms ; a large part of the remainder consisted of mammillated chalcedonic masses, some measuring 3 mm. in diameter. (Spheres very abundant, these with *Inoceramus* fragments and Foraminifera about 80 per cent.)
71	Yorkshire. Hessle, near the top of the zone	76·067	99·219	·031	·75	·781	Pale grey	Quartz	·31	·11	—	Haplophragmium, Ammodiscus, Trochammina	Much of this residue consisted of small mammillated chalcedonic masses of dull white colour. (Spheres about 40 per cent., *Inoceramus* prisms 5 per cent. ; very few Foraminifera other than the Spheres.)

* The four Devonshire specimens are from notes by Dr. Hume, *see page* 509.

† From notes by Dr. Hume.

C. THE TEREBRATULINA ZONE.

Microscopic Aspect.

The chalk of the last mentioned zone passes imperceptibly into that of the *Terebratulina* zone. The proportion of amorphous calcareous matter becomes gradually larger than in the zone below, and Spheres and shell-fragments are less conspicuous in size and number. The Spheres, moreover, become gradually less defined in outline, their exterior shell wall is thinner or is not seen at all, their centres are filled with fine amorphous matter similar to the surrounding matrix in which they are embedded, and the cells instead of standing out in strong relief and in the well-marked circles which are so characteristic of the zone below, are often mere shadowy representations of them. (See Plate VIII. Fig. 1). Not only are the Spheres thus altered, but the cells of the *Globigerina* are similarly affected, their walls being thinner and their general outline less prominent.

The character of the chalk of this zone seems fairly constant throughout all the area east and north-east of Dorsetshire. The features of many specimens from the Isle of Wight, Dover, and parts of Kent, the Midland counties, Norfolk, Lincolnshire and Yorkshire are much alike. From the base Spheres and shell-fragments become scarcer until about the top of the lower third of the zone is reached, the proportion of amorphous material increasing. In the middle third of the zone the greater part of the rock consists of fine amorphous calcareous paste, with comparatively few Spheres, shell-fragments or Foraminifera scattered through the mass. But as the summit of the zone is approached all these ingredients become gradually more abundant, though Spheres seem never so large or robust or numerous as in the zone of *Rhync. Cuvieri*.

The upper third of the zone is characterised in some localities by the occurrence of numbers of minute *Globigerina* and *Textularia*. This is particularly the case in a wide area of country S.W. and N.E. of Hitchin, also near Dover, and in the valley of the Medway, and again at Hessle, in Yorkshire. In a specimen from this last locality, probably about forty or fifty feet from the upper limit of the zone, Foraminifera though hardly so numerous are larger, and the number of *Globigerina* greater than in more southern samples.

Shell-fragments also increase in numbers in the higher parts of this zone, and some examples contain a considerable quantity of rather small angular calcitic particles.

In North Dorset this zone presents some exceptional features, and beds of hard chalk occur, which seem to indicate that conditions akin to those of the Chalk Rock had already set in in some parts of this county. A series of specimens from Cruxton, near Maiden Newton, were examined; those from the zone of *Rhynchonella Cuvieri* and from the lower part of the *Terebratulina* zone exhibit the usual features, but higher beds disclose an evident change of conditions, hard nodules occurring in the usually soft chalk of the zone. Thin sections of the nodules show that the chalk composing them is exceptionally full of small Foraminifera and small fragments of calcareous organisms, amongst which portions of the plates of Echinoderms can be recognised. Several sponge-spicules which appear to belong to the Monactinellid and one to the Tetractinellid group can be seen, and small grains of yellowish green glauconite also occur.

Still higher, but below the Chalk Rock, a well defined "rock bed" occurs. Here again the amorphous calcareous matrix is full of small foraminiferal cells, small *Globigerina* and *Textularia*, amongst which occur several larger specimens. There are also many calcareous fragments too small and too much broken up for identification except pieces of the plates of Echinoderms, but which from their diversity of appearance suggest other organisms than shells. Sponge-spicules also occur, and one or two grains of pale green glauconite. Between the hard beds the chalk is full of foraminiferal cells and finely comminuted calcareous particles, while glauconite occurs in all specimens from the highest parts of the zone.

In Devonshire also the chalk of the *Terebratulina* zone shows some variation in its structure compared with that of the eastern counties. The following is a description of a series from Beer Head.

A yellowish-white bed at the base of the zone, Beer Harbour.—Foraminiferal cells and Spheres are abundant, but there are very few *Globigerina* or other Foraminifera; all are well outlined. Sponge spicules, chiefly of Monactinellid types, are common, but two or three Tetractinellid forms occur, and in one place the nodes of some Hexactinellid mesh appear to be cut through. The spicular walls are in every case replaced by calcite. The larger calcareous fragments are for the most part *Inoceramus*-prisms, but a few pieces show the perforated structure. There are at least a dozen circular forms like those of Radiolaria figured as Nos. 1 and 2 in the Quart. Journ. Geol. Soc., Vol. 51, page 608.

Recognisable organic remains may be estimated in this specimen at about seventy-five per cent., with one or two mineral grains, but no glauconite; the remainder is the usual fine amorphous calcareous mud.

The same locality ten feet higher.—Foraminiferal cells and Spheres hardly so abundant; a few *Globigerina* and *Textularia* occur. There are but few calcareous fragments; and these are large and coarse, many showing the perforated structure of those seen in the Beer Stone. *Inoceramus* prisms are rare; there are also other particles, evidently of shell, and two or three small *Echinoderm* spines. No sponge-spicules are present. Glauconite in small green grains is rare.

From the Middle of the zone, Beer Harbour.—Chiefly amorphous material; many Spheres and foraminiferal cells occur, though they are not so abundant as in the specimens from lower in the zone; larger forms of *Globigerina* and *Textularia* are rare; all have their cell walls weakly outlined. There are many small shell-fragments.

The amount of recognisable organic particles may be estimated at about 35–40 per cent.

Results of the Examination of Washings.

Specimens both of the higher and lower part of this zone from Dover and from Hitchin were washed with water, and an attempt was also made to wash others from Mupe Bay (Dorset), Louth (Lincolnshire) and Hessle (Yorkshire), but the chalk from these localities was too hard to yield satisfactory results.

Shell Fragments.—*Inoceramus*-prisms were common in all specimens, but that from the higher part of the zone at Dover contained many fragments easily recognisable as those of *Terebratulina;* none were observed in the Hitchin sample. A few plates and pieces of rather large spines of *Echinoderms* occurred at both places.

A feature of the washings was the abundance of minute calcareous plates or ossicles. They were not like the smooth marginal ossicles of *Goniaster* (which also occur commonly), but have a complicated form rather difficult to describe, scarcely any two being exactly alike. Dr. Gregory, who kindly examined some of these ossicles at our request, says " they are the ambulacral ossicles of an *Ophiurid,* but to determine the genus is difficult." These peculiar plates or ossicles first appear in the top of the Lower Chalk, are fairly abundant in the *Belemnite* marls at Dover, but seem to be most numerous in the zones of the Middle Chalk.

Sponge-spicules are of rare occurrence, and have only been noted in the thin section of hard beds near the top of the zone.

Foraminifera.—The list of Foraminifera isolated from washings and residues is not large. Judging from the amount of material from Hitchin and Dover which was washed, these forms are not so abundant as in the Lower Chalk. The chalk at these localities is soft, and there should be no difficulty in obtaining specimens had they occurred. The list of the species identified by Mr. F. Chapman is as follows:—

	Mupe Bay.	Dover, Kent.	Hitchin, Herts.	Hunstanton, Norfolk.	Hessle, Yorks.
Rhizammina indivisa, *Brady*	–	–	–	–	x
Ammodiscus incertus, *d'Orb.* sp.	–	x	x	x	x
,, tenuis, *Brady*	–	–	–	x	–
,, gordialis, *J. & P.* sp.	–	–	–	–	x
Tritaxia tricarinata, *Reuss*	–	–	x	–	–
Gaudryina filiformis, *Berth.*	–	–	–	x	–
,, rugosa, *d'Orb.*	–	x	–	–	–
Textularia turris, *d'Orb.*	–	x	x	–	–
,, agglutinans, *d'Orb.*	–	x	x	–	–
Bulimina brevis, *d'Orb.*	x	x	x	–	–
,, Presli, *Reuss*	–	–	x	–	–
,, elongata, *d'Orb.*	–	x	x	–	–
,, Orbignyi, *Reuss*	–	x	–	–	–
,, affinis, *d'Orb.*	–	x	–	–	–
,, murchisoniana, *d'Orb.*	–	x	–	–	–
Bolivina textilarioides, *Reuss*	x	–	–	–	–
Marginulina sp.	–	–	x	–	–
Vaginulina recta, *Reuss*	–	x	–	–	–
Cristellaria cultrata, *Montf.* sp.	–	–	x	–	–
,, gaultina, *Berth.*	–	x	–	–	–
,, Bronni, *Roemer* sp.	–	x	–	–	–
,, convergens, *Born.*	–	x	–	–	–
Globigerina cretacea, *d'Orb.*	–	x	x	–	–
,, marginata, *Reuss* sp.	–	x	x	–	–
,, æquilateralis, *Brady*	–	x	–	–	–
Anomalina ammonoides, *Reuss* sp.	–	x	x	–	–
Pulvinulina sp.	–	x	–	–	–
Rotalia Soldan, *d'Orb.* var. nitida, *Reuss*	–	x	x	–	–

The *Globigerinæ* are particularly fine specimens, larger than at any other horizon in the chalk. Both *G. cretacea* and *G. marginata* are, perhaps, the commonest forms which occur.

With the exception of *Bulimina elongata*, and *Globigerina æquilateralis* all these species have been recorded from the Lower Chalk.

Examination of Residues.

Nine specimens of this zone were treated with the acid solution, including five by Dr. Hume.

The largest percentage of residue occurs in a specimen from the higher part of the zone at Dover, 3·68 per cent., while one from Beer Cliff, Devonshire, closely approaches this with 3·136 per cent., the specimens from Culver Cliff (Isle of Wight) and Luton, Bedfordshire, come next with 2·24 per cent. and 2·56 per cent. respectively. The purest chalk again occurs in the east and north-east, that from north-west Norfolk giving a residue of only ·776 per cent., and that from Hessle, Yorkshire, still less, ·752 per cent.

Though the largest percentage of coarse residue occurs in the examples from Beer Cliff, Culver Cliff, and Hessle, this appears to be due to the presence of secondary rather than to detrital minerals. Thus, in both the Culver and Hessle samples a large proportion consists of iron oxide, while Dr. Hume notes that the coarse residue in the Beer Head sample consists largely of chalcedonic aggregates and limonite. The two specimens which appear to contain most detrital minerals are those from Mupe Bay and Afton Down. Although in the first of these the coarse residue is only ·010 per cent., it consisted chiefly of mineral grains.

The green-coated nodule bed at Afton Down, from which Dr. Hume obtained his specimen, recording it as Chalk Rock, is below that horizon, and is included by us the zone of *Terebratulina* (see p. 410). This, like the Mupe Bay specimen with which it may be compared, appears to be rich in detrital minerals.*

Detrital Minerals.—Quartz is again the most abundant mineral in the residues. Dr. Hume recognises Mica (muscovite and biotite) in the specimen from Beer Cliff, Devon; and Augite, Hornblende, and Tourmaline in that from Afton Down. Amongst the detrital mineral grains in the specimen from Ringstead, Norfolk, Mr. Teall can identify Orthoclase. The largest grains occur in examples of the zone from the West of England; in that from Beer Cliff Dr. Hume records ·40 mm. as the maximum size, and grains up to ·31 mm. in their longest diameter occurred at Mupe Bay. The average size, however, scarcely exceeds ·10 mm. in any locality.

The quantity of mineral particles which occur in each residue is exceedingly small.

Secondary Minerals.—Many grains of glauconite occur in the chalk of this zone from Devonshire, but elsewhere it is of rare occurrence in the residues.

The coarser portion of the residues consists chiefly of fragments of red ferruginous iron oxide, usually porous and easily crushed. In the residue from Hessle parts of four separate individuals of *Terebratulina* occurred as casts in this material, one of them being nearly perfect.

Fragments of siliceous network, or fragments of *Inoceramus* shell silicified interprismatically, with a few flat flakes of silicified shell were noted in nearly all residues.

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* Chemical and Micro-Mineralogical Researches, p. 53, *et seq.*

We append the notes writen by Dr. Hume on the residue of the sample from Beer which was analysed by him.

"**Terebratulina Zone** (half-way up Beer Cliff).—This zone yielded a considerable residue; the part coarse enough to be examined weighed ·077 grammes and consisted largely of chalcedonic aggregates, limonite, a large number of minute globular casts of Foraminifera, sometimes still united, and showing to have been formed in the tests of the delicate species *Textularia globulosa*. Glauconitic rods are abundant, while flakes of muscovite and biotite form an important element. Quartz is represented by three or four larger fragments ·4 mm. in diameter, a fine quartzose residue being practically absent. ·038 grammes of the residue consists of the chalcedonic meshes previously referred to.

"The finer material consists of—(1) Yellow ochre and red aggregations of limonite, which break up easily when submitted to light pressure. One piece is covered with minute botryoidal projections. (2) Foraminiferal tests which have undergone extreme chalcedonification. The most striking objects in this respect were forms which have been probably derived from some form of *Nodosaria*. The chambers have become somewhat distorted, but their individuality is still marked, and the final chamber of the series terminates in a pointed extremity, such as is common in many species of *Nodosaria*. On being touched with a brush these immediately broke to pieces. (3) Light yellow glauconitic casts of Foraminifera are abundant, the largest of these, expanded into a large triangular chamber after the manner of *Cristellaria*, is ·166 mm. in length, but the majority of the rounded single chambers are about ·08 mm. diameter. In addition to these occur spheres joined together by stoloniferous connections, these presenting several varieties. In one case three are connected together, one being in a different plane from the other two; again, there are irregular aggregations of five or more chambers, as in some *Globigerinæ*, and, lastly, there is the regular arrangement of alternating foliaceous chambers on two sides of a central axis, as in *Textularia*. Some of these glauconite grains are still inclosed in the silicified tests. (4) In addition, there are glauconite rods, some 4 mm. in length, none showing any terminal projection or ornamentation, but which, nevertheless, from analogy are probably the internal casts of sponge-spicules. (5) Muscovite and biotite mica flakes of small size are present, but no heavier minerals have been observed.

"This zone, therefore, shows a considerable diminution in the detrital materials present, and also begins to show evidence of the presence of sponge spicules which play such an important part in the zone of *Holaster planus*. A noticeable feature is the exceedingly small amount of quartz in the residue."

W. F. HUME.

COMPOSITION OF THE FINE RESIDUE.

As in the case of the Lower Chalk the finest material of the chalk composing the zones above described may be classed under the following different heads :—

1. Definite calcitic crystals which have probably been formed since the deposition of the rock. 2. Minute particles probably derived from shell. 3. Thin flakes often perforated and doubtless derived from the tests of Foraminifera. 4. Crystalloids and kindred forms. 5. Very minute particles too small as a whole to give any clue to their derivation, though some may be recognised as broken crystalloids.

The difference between the finest material of the *Rhynchonella Cuvieri* zone and that of the *Terebratulina* chalk may almost be anticipated. In the shelly lower zone the matrix of the rock contains a larger proportion of calcitic particles and crystals, the former probably derived from the numberless *Inoceramus* prisms with which the rock abounds ; in fact, it is possible to find particles which come away in the finest washings of whose identity as minute pieces of a prism there can be little doubt. Not only are large particles present in greater numbers, but the mass of the rock seems to consist largely of calcitic crystals, minute, it is true, but large enough to possess a definite outline, and giving a very finely-granular effect when mounted in balsam and viewed under the microscope with an objective of one-tenth inch focus.

We were, moreover, struck by the fact that much of the matter held in suspension in the water after washing a specimen of the zone of *Rhynh. Cuvieri* subsided more rapidly than that of the overlying zone.

Crystalloids are abundant in both zones; in the zone of *Rhynchonella Cuvieri* circular forms seem to predominate, but those of elliptical shape are also very common. None were like the true coccolith, the shirt-stud form was not seen.

The constitution of the matrix of the *Terebratulina* chalk is very similar to that of the underlying zone, except that particles which may be referred to shell and the larger calcitic crystals are less numerous, the minute calcitic particles forming the greater part of the material.

The amorphous inorganic matter, the presence of which is quite appreciable in the lower beds of the Chalk, cannot be recognised at this horizon.

The fine clay of the residues presents no feature of interest. Mounted in Canada balsam it appears structureless matter, containing here and there a minute particle of some mineral.

TABULATION OF RESULTS—TEREBRATULINA ZONE.

Number.	Locality.	Amount of Material.	Per cent. Soluble in Acid.	Per cent. of coarse Residue.	Per cent. of fine Residue.	Total per cent. Residue.	Composition of Coarse Residues.						Remarks.
							Colour.	Detrital Minerals.	Maxim'm size of Grains.	Average size of Grains.	Secondary Minerals.	Foraminifera.	
		gr'mes.							mm.	mm.			
72	*Devonshire Beer Cliff	71·19	96·86	·1091	3·027	3·136	—	Quartz, mica, muscovite, and biotite.	·40	—	Glauconite, limonite.	? Nodosaria, ? Textularia, ? Cristellaria (all casts).	This residue consisted largely of chalcedonic aggregates, limonite, &c. The glauconite was in rod-like lengths. Many foraminiferal casts in limonite and glauconite.
73	Dorsetshire. Mupe Bay, 15ft. below the bed of green-coated nodules.	55·784	98·16	·010	1·84	1·85	Grey	Quartz	·31	·11	Iron oxide	—	About half the coarse residue consisted of mineral grains, chiefly quartz, and one-fourth more was small masses of iron oxide. Three or four flat pieces of silicified shell occurred, with a little mesh-work and silicified *Inoceramus*. Very few Foraminifera. (Organic contents were nearly all small spheres, these with a few pieces of shell, forming 75 to 80 per cent. of the chalk.)
74	† Isle of Wight. Culver Cliff	80·78	97·76	·112	2·12	2·24	Light Brown	Quartz	—	—	Red ferruginous oxides.	Ammodiscus, Haplophragmium, Textularia, ? Astrorhiza.	The heavy residue consisted chiefly of red ferruginous oxides, with very few mineral grains.
74	† Afton Down	79·58	91·16	·048	1·80	1·84	Dark Brown	Quartz, augite, hornblende, tourmaline.	·13	—	Glauconite (·06 mm.).	Ammodiscus	The glauconite occurs in grains of rounded outline and of dark olive-green colour ; a few rods.
76	Kent. † Dover (Higher)	74·54	96·32	·0052	3·68	3·68	—	—	‡ ·20	·10	—	‡ Rhizammina, Ammodiscus, Bulimina, Haplophragmium.	The whole insoluble residue, Dr. Hume remarks, consists of a few unrecognisable organic fragments. To obtain the size of the mineral grains we treated two of our own specimens ; the percentnges were almost the same in total, but we obtained a larger coarse residue.
	(Lower)	73·40	98·57	·0022	1·43	1·43	—	—	‡ ·14	·08	—		
77	* Bedfordshire. Midland Railway cutting, Luton.	83·00	97·44	·0057	2·55	2·56	—	—	—	—	—	—	(A section of the chalk of this zone in this locality shows the chalk to be chiefly amorphous material : the recognisable particles and Foraminifera do not exceed 10 per cent.)
78	Norfolk. Ringstead, near Hunstanton (base of the zone).	70·130	99·23	·0085	·708	·776	—	Quartz, orthoclase.	·21	·08	Iron oxide	Ammodiscus. Gaudryina.	Much of the coarse residue was of minute pieces of indeterminable siliceous matter. One or two silicified flakes occurred, and a little mesh-work. (Spheres about 35 per cent. ; shell-fragments about 5 per cent.)
79	Yorkshire. Hessle (near the top of the zone).	87·146	99·24	·104	·648	·752	—	Quartz	·27	·27	Limonite	Rhizammina, Ammodiscus.	The coarse material of this residue was almost entirely limonite, and included casts of four separate specimens of *Terebratulina*, one of which was nearly perfect. Only six or eight quartz grains. (Very few shell-fragments, but Foraminifera and cells comparatively numerous, with a few spheres—about 18 per cent.)

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* From notes by Dr. Hume.

† "Chemical and Micro-Mineralogical Researches," pages 52 and 68.

‡ From specimens of our own collecting.

General Summary.

In the case of the Lower Chalk our study of the chemical and micro-mineralogical aspects disclosed many features of interest. Considerable differences were shown to exist in the nature of the deposit when specimens from different localities and horizons were examined, and it was possible to follow a lateral as well as a vertical change from a calcareous marl to a nearly pure calcareous rock, with a sudden recurrence of argillaceous matter at the top.

These features are not repeated in the Middle Chalk, and we have to deal with a material more homogeneous in its nature, the zones of this division showing none of the marked differences which occur in the Lower Chalk. The hard nodular Melbourn Rock, which makes so well marked a base to this division over a large area, seems to have been formed during a time when the sea-floor was swept by a steady current. The nodules which are so prominent a feature of this bed, are not phosphatic concretions, but seem to have been the firmer parts of an original deposit which resisted the effects of the current action; they are different in character to the surrounding matrix, which, though variable in its aspect, is usually full of shell-fragments. These appear to have been sorted out from the fine mud by a slight current, for in several thin sections they have the appearance of having been arranged round the nodule as though by the action of slowly moving water. The results of chemical analysis of this bed do not suggest that the current bore with it terrigenous material, for the percentage of the residue is everywhere less (for each locality) than in the highest bed of the zone of *Holaster subglobosus*. The amount of the coarse residue is everywhere very small, and much even of this consists of peculiar organic meshwork which may probably be referred to sponges.

In the overlying chalk the nodular character of the rock gradually disappears and analysis of specimens (with one exception) shows that the amount of fine inorganic material mingled with the calcareous mud diminishes. The exception is a specimen analysed by Dr. Hume from Swanage, Dorset, from which he obtained a residue of 7·72 per cent., none of the other examples exceeding 2·28 per cent.

Western examples, however, still exhibit the more decided traces of adjacent land, and we find, from Dr. Hume's notes, that in the zone of *Rhynchonella Cuvieri* in Devonshire terrigenous material is still a feature of the deposit. Though the amount of detrital minerals is small, yet it is possible to identify amongst them fragments "such as would be derived from the igneous rocks of the south-western counties." These mineral fragments are, however, not so abundant in the base of the zone as in the limestone locally known as Beer Stone. In this Dr.

Hume records sand grains as large as ·88 mm. in their longest diameter, while in the same zone at Lulworth the maximum in ·48 mm. Except in the Swanage specimen, the amount of fine clay is slightly larger than in the south-eastern and midland counties.

The characteristic feature of these two zones does not lie with the inorganic but with the organic constituents of the rock. Thin sections viewed under the microscope show that Spheres are extraordinarily abundant, and the deposit is crowded with them, no matter from what locality the specimen comes. M. Cayeux also notices this feature in the chalk of the Paris basin.*

In some specimens from the zone of *Rhynchonella Cuvieri* these minute bodies form 70 or 80 per cent. of the rock. Their outline is usually though not always well defined, the test a well marked ring and their interiors filled either with fine calcareous paste or minute calcitic crystals. These organisms, though often locally abundant in the Lower Chalk, are never so constant a feature as at this horizon. Associated with the Spheres are *Globigerina* and *Textularia;* in the former the walls of the tests are seen to be well marked in the thin sections of the rock, though they are not so thick as those found in sections of Atlantic mud, and the number of specimens occurring in a thin slice, though variable, is never so large as in the modern oceanic deposit. Another feature of this zone is the abundance of the prisms of *Inoceramus*-shells, which are doubtless derived from *Inoceramus mytiloides* so abundant in this zone.

There can be no doubt that the lower part of the Middle Chalk is built up chiefly of disintegrated *Inoceramus*-shells, Foraminifera, and Spheres, though Echinoderms, Star-fish, Bryozoa, and other calcareous organisms have added their quota to the deposit.

There is no marked divisional line between this zone and that of *Terebratulina*, the conditions of one passing gradually to those of the other. Spheres gradually become less numerous, their shells thinner, their outline less defined, until above the lower third a large part of the rock of this zone consists of amorphous calcareous material, giving no evidence of its derivation.†

It is not until quite the upper part of the zone is reached that Spheres and Foraminifera again begin to appear conspicuously in thin sections of the rock, and their tests partially regain the clear definition and robustness seen in the zone of *Rhynchonella Cuvieri.* In this part of the zone in some localities minute *Globigerina* and *Textularia* are more common than usual.

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* See Contribution à l'étude Micrographique des Terrains Sédimentaires, by M. L. Cayeux, p. 454.

† See also Cayeux, *op. cit.*, p. 456.

In Dorset and Devon the higher parts of the zone show signs of a change of conditions; the chalk becomes full of small Foraminifera and Spheres and minute shelly fragments; small yellowish grains of glauconite, nearly absent in samples of this zone from the midlands and south-eastern counties, make their appearance. Sponge-spicules are of frequent occurrence, some beds assume the character of a semi-crystalline limestone, and the general conditions seem somewhat similar to those of the Chalk Rock.

Of the organisms which occur in the Middle Chalk, Spheres and *Inoceramus*-prisms have already been alluded to, but another constant feature deserves notice, viz., the number of minute ossicles of peculiar character which have been recognised by Dr. Gregory as the ambulacral plates of an *Ophiurid.* These plates are especially numerous in the *Terebratulina* zone, though they occur commonly in the lower zone as well.

The number of Foraminifera obtained from washings and residues is not so large as in the Lower Chalk, and those isolated do not show much variation when the species of this division are compared with those of the Lower Chalk. Judging from the results of the washings, Foraminifera are not very abundant, for, as we have already stated, the amount of material used was quite as large as that from the lower division, and its condition in the *Terebratulina* zone was favourable to the separation of these forms.

Arenaceous Foraminifera are comparatively rare, but short lengths of arenaceous tubes, probably fragments of *Rhizammina*, form a considerable part of many of the residues. The most persistent forms are those of *Ammodiscus*. *Globigerina cretacea* and *Globigerina marginata* were both fairly common in the washings, but it may be remarked that their numbers are not greatly in excess in their proportion to other Foraminifera. It is difficult to estimate what proportion they bear to the mass of the Chalk; certainly it is not a very large one, and individually they are far less abundant than in specimens of Atlantic ooze in our possession. Judging from thin sections, they appear to be most abundant in the lower part of the Middle Chalk, especially in such sections as contain many shell-fragments, and where the heavier particles seem sorted out, presumably by current action. Thin sections also show that the shells of Foraminifera in the *Terebratulina* zone become thin, though the specimens of *Globigerina* isolated from the lower part of this zone were especially fine, larger in fact than from any other horizon in the Chalk.

Sponge spicules are rare in the Middle Chalk, and are only conspicuous in the hard beds at the summit of the division in the west of England.

The following is a list of all the Foraminifera identified by Mr. Chapman from our washings and residues:—

MIDDLE CHALK FORAMINIFERA.

——	Zone of Rhynch. Cuvieri.		Zone of Ter. gracilis.
	Melbourn Rock.	Higher Beds.	
Rhizammina indivisa, *Brady*	–	x	x
Reophax sp. nov.	x	–	–
Haplophragmium sp.	–	x	x
Ammodiscus charoides, *J. and P.*	x	x	x
,, gordialis, *J. and P.* sp.	–	x	x
,, incertus, *d'Orb.*	x	–	x
,, tenuis, *Brady*	–	–	x
Trochammina sp.	x	–	–
Textularia agglutinans, *d'Orb.*	–	–	x
,, minuta, *Berth.*	x	–	–
,, trochus, *d'Orb*	–	x	x
,, turris, *d'Orb.*	–	x	x
Tritaxia tricarinata, *Reuss*	–	–	x
Gaudryina filiformis, *Berth.*	–	x	x
,, rugosa, *d'Orb.*	–	–	x
Bulimina affinis, *d'Orb.*	–	x	x
,, brevis, *d'Orb.*	–	x	x
,, elongata, *d'Orb.*	–	–	x
,, Orbignyi, *Reuss*	–	–	x
,, Presli, *Reuss*	–	x	x
,, murchisoniana, *d'Orb.*	–	–	x
Bolivina textularioides, *Reuss*	–	–	x
Marginulina, sp.	–	–	x
Vaginulina recta, *Reuss*	–	–	x
Cristellaria cultrata, *Montf.*	–	x	x
,, gaultina, *Berth.*	–	–	x
,, Bronni, *Roemer*	–	–	x
,, convergens, *Born.*	–	–	x
Globigerina cretacea, *d'Orb.*	–	–	x
,, marginata, *Reuss.*	–	x	x
,, æquilateralis, *Brady*	–	–	x
Anomalina ammonoides, *Reuss* sp.	–	x	x
Truncatulina ungeriana, *d'Orb.*	–	x	–
,, lobatula, *Walker* sp.	–	x	–
,, akneriana, *d'Orb.*	–	x	–
Pulvinulina sp.	–	–	x
Rotalia Soldani, *d'Orb*, var. nitida, *Reuss*	–	x	x

CHAPTER XLV.

THE CHEMICAL COMPOSITION OF MIDDLE CHALK.

Analyses of Middle Chalk do not bring out much variety of chemical composition. The hardness of the Melbourn Rock and of certain beds in the *Terebratulina* zone appears to be due partly to the slow accumulation of the material of which they are formed, and partly to subsequent changes by which these particular beds were rendered denser by the infiltration of crystalline carbonate of lime or calcite; the amount of this calcite being greater in some places than in others.

The Chalk of the Rhynchonella Cuvieri Zone.

The following is an analysis of Melbourn Rock taken from the cutting on the railway one mile south of Burghclere, Hants, and made by Mr. J. T. Hewitt (late of St. John's, Cambridge); published in Papers of the Hants Field Club, No. ii., p. 72 (1888).

Silica - - - - - - - - -	7·99
Lime - - - - - - - - -	49·07
Magnesia - - - - - - - -	trace
Peroxide of iron - - - - - - -	·33
Carbonic acid - - - - - - -	38·53
Phosphoric acid - - - - - - -	4·15
	100·07

In this analysis the amount of silica is unusually large and the proportion of lime is not sufficient to be in combination with both the phosphoric and the carbonic acids, so that it does not seem to be reliable.

Messrs. Way and Paine give an analysis of a "very hard yellowish chalk, mixed with broken chalk fossils, and lying between the last marl (*i.e.*, Grey Chalk), and the chalk with flints."* This sample was doubtless from near the lower part of the *Rhynchonella Cuvieri* zone. They also give one of the lower portion of the Chalk with flints (? upper part of Middle Chalk). Both were obtained near Farnham. These two analyses are copied below:—

	1.	2.
Clay and sand, insoluble in acid - - - -	2·04	·66
Carbonic acid - - - - - - -	42·14	42·98
Sulphuric acid - - - - - - -	·31	trace
Phosphoric acid - - - - - - -	·07	·08
Lime - - - - - - - - -	54·37	55·24
Magnesia - - - - - - - -	·25	·10
Potash - - - - - - - - -	·08	·06
Soda - - - - - - - - -	·19	·14
Oxides of iron - - - - - - -	·55	·74
	100·00	100·00

The amount of carbonate of lime in the first sample will be over 95 per cent., and in the second about 98 per cent.

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*Journ. Roy. Agric. Soc., Vol. xii., p. 552 (1852).

The following samples, taken from different parts of the Middle Chalk, were sent to Professor J. B. Harrison, the Government Chemist of British Guiana, who kindly undertook to have them analysed in the Laboratory at Georgetown under his own superintendence, the method employed being that devised by him for separating the different siliceous ingredients. The horizons and localities of the samples are :—

No. 1. Melbourn Rock, Okeford Fitzpaine, Dorset, lower part.
No. 2. Melbourn Rock from the same place, upper part.
No. 3. Chalk, 50 feet above Melbourn Rock, Hitchin, Herts.

		1.	2.	3.
	Organic matter, etc. - - - -	·57	·50	·10
	Quartz - - - - - - -	·55	·30	·15
	Colloid silica - - - - -	·65	·45	·35
Silicates and Clay.	Combined silica - - -	1·25	·29	·23
	Iron peroxide - - - -	·40	·26	·28
	Alumina - - - - -	·39	·39	·77
	Inorganic Oxide - - -	·28	·05	·23
	Calcium oxide - - -	—	·05	—
	Magnesia - - - - -	·02	·35	traces
	Potash - - - - -	·16	·04	·14
	Soda - - - - - -	trace	trace	·13
	Calcium sulphate - - - -	·17	·41	·29
	Calcium carbonate - - -	95·20	97·02	96·15
	Magnesium carbonate - - -	·68	—	1·34
		100·32	100·11	100·16

Traces of chlorine were found in all of them.

Summarising the results of the above analyses, and arranging the ingredients more nearly in order of relative importance, they may be expressed as below :—

	1.	2.	3.
Calcium carbonate - - - -	95·20	97·02	96·15
Magnesium carbonate - - -	·68	—	1·34
Calcium sulphate - - - -	·17	·41	·29
Silicates - - - - - - -	2·50	1·43	1·78
Colloid silica - - - - - -	·65	·45	·35
Quartz - - - - - - -	·55	·30	·15
Organic matter - - - - -	·57	·50	·10
	100·32	100·11	100·16

It will be noticed that these are all very pure limestones, and that the amount of crystalline silica or quartz in them is very small indeed. The amount of clay in the Melbourn Rock varied only from 1·4 to 2·5 per cent., and the total amount of siliceous matter in the lower sample of this rock is only 3·70.

Mr. R. A. Berry has kindly placed at my disposal the following analysis of a sample of chalk from the zone of *Rhynch. Cuvieri* obtained by himself at Hitchin:—

Calcium carbonate	93·88
,, phosphate	·31
Excess of lime	2·91
Magnesium carbonate	·67
Oxide of iron and alumina	·27
Manganese dioxide	·58
Colloid silica	·72
Clay and quartz	·27
Loss in analysis	·39

The excess of lime in this analysis is difficult to account for, and the amount of calcium carbonate is small compared with other analyses, but Mr. Berry only obtained 41·66 of carbonic acid from the material.

Professor Barrois has published an analysis by M. Duvillier of a sample of nodular chalk from the zone of *Rhynchonella Cuvieri*, obtained by him from St. Catharine's Hill, near Winchester; it is as follows (see "Recherches," 1876, p. 41):—

Clay and sand	·72
Soluble silica	·06
Oxide of iron	·20
Phosphate of lime	·12
Carbonate of lime	98·35
Carbonate of magnesia	·40
	99·85

The following analysis of the Beer Stone of Devonshire was made by Mr. Charles Ekin, F.I.C., F.C.S., who kindly places it at our disposal. The sample was taken from the quarry by himself in 1899. When thoroughly air-dried it yielded—

Silica and silicates	4·18
Ferricoxide and alumina	·76
Carbonate of calcium	93·38
Carbonate of magnesia	1·12
Moisture	·18
	99·62

This agrees very nearly with Dr. Hume's result (see p. 513), who found 3·45 of siliceous residue in one sample of Beer Stone.

Mr. Ekin also analysed some of the hard knotty lumps which occur in the zone of *Rhynchonella Cuvieri* along the coast. He notes that this hard chalk was semi-crystalline, while the surrounding chalk had the usual earthy and amorphous appearance. The results obtained were as follow:—

	Hard Chalk.	Soft Chalk.
Loss on drying at 120 degs. C.	3·52	·24
Carbonate of calcium	93·5	95·
Silica and silicates	·73	·78
Chlorine	1·228	·085
	98·978	96·105

The amounts of chlorine would be equal to 2·023 and ·14 respectively of chloride of sodium, and its presence is doubtless due to the saturation of the rock by the sea-spray.

The following is an analysis by Mr. Prangley of a sample of hard chalk used as a flux in smelting the brown iron-ore of the Corallian Beds at Westbury, Wiltshire. The specimen formed part of a series exhibited by the Westbury Iron Company in the International Exhibition of 1862, and afterwards presented to the Museum of Practical Geology.

Inquiry at the works elicited the information that the chalk was obtained from the large quarry on Westbury Hill; the lower part of the chalk there exposed is hard, and belongs to the zone of *Rhynchonella Cuvieri*, not far above the Melbourn Rock (see p. 454).

Water	.260
Organic matter	1.865
Silica	1.110
Carbonate of iron and traces of alumina	2.677
Phosphate of lime	.523
Carbonate of lime	93.104
Carbonate of magnesia	.188
Sulphate of lime	.132
Chloride of sodium	trace
Loss	.141
	100.000

CHALK OF THE TEREBRATULINA ZONE.

Very few analyses of this part of the chalk appear to have been made, probably because it is not very frequently exposed in quarries, and has been dug chiefly for burning into lime and making into whitening. It is a very pure chalk, and, so far as it has been examined, it never contains less than 96 per cent. of carbonates, and sometimes has as much as 99 per cent. (see table on p. 521).

The analysis of a Chalk which was probably taken from this zone near Farnham in Surrey has already been given (p. 526).

Mr. R. A. Berry has made an analysis of a sample from the "upper part of the Middle Chalk" at Royston, and has kindly placed the result at our disposal, this is as follows:—

Calcium carbonate	85.93
,, phosphate	.80
Excess of lime	5.85
Magnesium carbonate	3.63
Oxide of iron and alumina	.21
Manganese dioxide	.15
Colloid silica	1.48
Clay and quartz	1.20
Loss on ignition	.17
Loss in analysis	.58
	100.00

A sample of the layer which breaks into columnar or rectangular pieces at the base of this zone in Lincolnshire, was analysed by Mr. Grant-Wilson, of the Geological Survey, with the following result*:—

Insoluble in hydrochloric acid, chiefly alumina	1.06
Soluble portion—	
Carbonic acid	43.05
Sulphuric acid	.45
Lime	54.63
Magnesia	.39
Manganese	trace
Protoxide of iron	.35
Alumina	.24
	100.17

These ingredients may be combined as follows:—

Carbonate of lime	96.88
Carbonate of magnesia	.81
Sulphate of lime	.76
Alumina and iron oxide	.59
Insoluble silica and alumina	1.06
	100.10

The following analysis of chalk is taken from a "Report on the Soils of Kent and Surrey to the Technical Education Committees," by A. D. Hall and F. J. Plyman, of the Agricultural College at Wye (1902). Mr. Hall informs me that the sample came from a pit about three-quarters of a mile east of Wye, and 300 feet above the outcrop of the Gault. The chalk was dried at 100° C.

Insoluble Residue	2·480
Soluble—Lime	52·750
Magnesia	·211
Ferric Oxide	·067
Alumina	·113
Potash	·098
Soda	·013
Oxide of Manganese	·149
Soluble Silica	·035
Sulphuric Acid	·082
Phosphoric Acid	·106
Chlorine	·006
† Carbonic Acid	37·670
‡ Organic matter and combined water	5·400
	99·180

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* Quoted from the Geology of East Lincolnshire. Man. Geol. Survey, 1884.

† Equal to 85·61 of Calcium Carbonate.

‡ Mr. Hall informs me that most of this amount is probably organic matter, and that the combined water is not likely to exceed 1·5 per cent.

CHAPTER XLV.

WHITE CHALK AS COMPARED WITH RECENT CALCAREOUS OOZES.

In dealing with the Lower Chalk we ventured to compare its material with the calcareous oozes now being deposited in certain enclosed seas, such as the Gulf of Mexico. The Middle and Upper stages of the Chalk differ from the Lower in consisting of much purer material. *A priori*, therefore, it would seem natural to suppose that this purer material was formed in deeper water and at a greater distance from land than that of the Lower Chalk. This conclusion, however, has been disputed, and several eminent authorities have declared that no part of our Chalk formation is comparable with any modern oceanic deposit.

It seems necessary, therefore, to discuss the general question of whether such a comparison can be made before we deal with special evidence regarding the conditions under which the Middle Chalk seems to have been accumulated.

1. Points of Resemblance and Difference.

Much has been written respecting the similarity between the material of the chalk and that of *Globigerina* ooze; some have declared the resemblance to be very great, and have regarded "the chalk" as an ancient foraminiferal and oceanic deposit analogous to the *Globigerina* ooze now found on the Atlantic floor; others (including Sir J. Murray) have pointed out certain marked differences between them, and have declared that they cannot have been formed under the same physical and geographical conditions.

It appears to me that this is a subject on which it is possible to take too wide and general a view on the one hand, or a too limited and restricted view on the other; and that a really valid opinion can only be arrived at by careful steering between these two extremes, and by a more thorough consideration of the facts and possibilities than anyone has yet attempted.

For instance, until about ten years ago most of the writers who discussed this question spoke of "the chalk," or "la craie," as if its composition was similar throughout, utterly ignoring the existence of such beds as the Melbourn Rock and the hard beds which occur in the zone of *Holaster planus*; to say nothing of the more minute differences which are observable by the aid of the microscope. The careful investigations carried out by Dr. A. S. Hume and Mr. W. Hill (Chapter xxii. & xliii.) have shown decisively that there are great differences in the composition of "chalk," according to the zonal age of the material. As these differences have become known, it has become evident that it is most unscientific to compare the Chalk as a whole to *Globigerina* ooze as a whole. Each stage of the Chalk and each part of such a stage must be considered separately, and more work is yet required in the investigation of the lithological differences presented by each zone in its extension from area to area.

Again, there are several ways in which too limited a view of the analogies between chalks and modern oozes may be taken. It is obvious that an observer who bases his conclusions on the examination of chalks obtained from a single district will not have the requisite material for comparison. Thus, the Middle Chalk of the extreme north-eastern part of France may have been formed in comparatively shallow water, but it does not follow that chalk of the same age but of much purer character in the central and western parts of the Paris Basin was formed in water of the same depth.

Again, we must not forget that the Cretaceous chalks are ancient deposits, that they have been raised above sea-level for a long time, and have been exposed to the action of percolating waters, and have been saturated with fresh water up to various levels at various times and places. There can be no doubt that some important changes have been effected in the minute structure and composition of the Cretaceous chalks since they were at the bottom of the sea, and the scope of these changes must be considered, but we do not think they can be credited with the entire removal of *Globigerina* or of other *Foraminifera*.

In this connection the Tertiary chalk of Barbados becomes of the greatest importance, because it forms part of a series of beds which are unquestionably comparable with the Red Clays, the *Radiolarian* ooze, and the *Globigerina* ooze of the modern oceans. At the same time, Barbadian chalk presents a very close resemblance to English white chalk, not only in its general aspect but in its structure, and especially in the small proportion of perfect *Foraminifera* to the mass of the fine-grained powdery matrix.*

In the same way with regard to modern deposits it ought to be remembered that *Globigerina* ooze is a general name for a class of deposits, and not for a single variety of nearly constant composition. The exploration of the oceanic depths by the *Challenger* and other expeditions have greatly enlarged our knowledge, and have resulted in a useful general classification of marine deposits, but it is possible that in this excellent general view the local differences presented by each kind of deposit have not been sufficiently allowed for, and perhaps they are not yet sufficiently understood. It is useful to have a general name like "*Globigerina* ooze," but no one can peruse the *Challenger* Report on Deep Sea Deposits without realising that there are many varieties of such ooze. The investigators have always been careful to say that *Globigerina* ooze passes into red clay on the one hand and into *Pteropod* ooze or into green mud on the other; but geologists would have been grateful for a more complete description of some of these gradations and varieties of deposit, and especially of those which occur in the lesser depths of the oceanic basins, or in such areas as the Caribbean Sea.

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*See Geology of Barbados, Quart. Journ. Geol. Soc., Vol. xviii., p. 179 (1892).

Professor A. Agassiz has drawn attention to some of the differences which the calcareous oozes exhibit in the Caribbean Sea and the Gulf of Mexico.* He speaks of them as modified *Globigerina* and *Pteropod* oozes, and Sir J. Murray in his report on the samples submitted to him says: † "It should be remembered, however, that both in the size of the mineral particles and in the nature of a large number of the calcareous particles these deposits differ considerably from similar deposits found far away from land in the open ocean, and called also *Pteropod* and *Globigerina* oozes." It does not appear that any samples from the central parts of the Caribbean sea were examined.

The principal difference between the purer white chalks and the more calcareous oceanic oozes described in the *Challenger* Report on Deep Sea Deposits, consists in the relative proportions of perfect or nearly perfect Foraminifera to the mass of the deposit. In the modern oceanic deposits the shells of pelagic Foraminifera are very abundant; they generally make up about half the actual mass of the deposit, and in the case of many Globigerina oozes they form between 70 and 80 per cent. of the mass. The following table has been compiled from statements given in the *Challenger* Report:—

———	Proportion of Pelagic Foraminifera.		Proportion of Foraminifera living on Bottom.
	From	Average	Average.
In Globigerina ooze -	25 to 80	.. 53.1	2.13
In Pleropod ooze - -	30 to 75	.. 47.15	3.15
In Coral mud - -	10 to 56	.. 31.27	14.64
In green mud - -	1 to 35	.. 14.59	2.94

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* Three Cruises of the *Blake*, Vol. i., p. 281, and map on p. 286 (1888).

† Bull. Mus. Comp. Zool., U.S., Vol. xii., p. 45 (1885).

On the other hand, with whiter chalks of the Cretaceous System the relative proportion of recognisable Foraminifera is generally small. It is a curious fact that this was pointed out by Dr. Mantell so long ago as 1845[*]; it was re-stated by Mr. Hill in 1889[†] and independently by M. L. Cayeux[‡] in 1891, and was discussed at length by the same author in 1897.[¶] M. Cayeux points out that the abundance of Foraminifera varies greatly in different localities, that in some cases they do not form more than 5 per cent. of the mass, though in others they may amount to as much as 75 or 80 per cent., but it must be remembered that in this amount he includes what we call Spheres. Mr. Hill informs me that in English chalks of the Middle and Upper divisions, the proportion of Foraminifera is always small, and that though there are some horizons and localities where they are more abundant than usual, the average proportion is not more than 10 per cent. of the mass, and is often only about 5 per cent. (excluding Spheres).

With respect to the *Globigerinæ* in particular, they cannot be regarded as the dominant form in Cretaceous chalk. M. Cayeux says (op. cit., p. 457) that "the rôle of *Globigerinæ* is on the whole quite secondary, and is often almost negligeable." This statement is confirmed by Mr. Hill, who writes as follows :—" As to *Globigerinæ*, though fairly common in Melbourn Rock and in Chalk Rock, and though some specimens of chalk contain a few more than others, I entirely agree with M. Cayeux that they are frequently a negligeable quantity in the constitution of the chalk." He further remarks that the genus *Textularia* is in reality the dominant form of foraminiferal life in the English Chalk. This is in accordance with observations made long ago by Ehrenberg and Mantell.

There are two other particulars in which some of the Turonian and Senonian chalks, both in England and France, differ from modern deep-sea deposits. These are the presence often in great abundance of the spherical calcareous bodies described on p. 500, and the frequent occurrence of small angular shell-fragments. Both Spheres and shell-fragments are often so numerous that they must be regarded as important constituents of the Chalk as a whole, though the quantity of each of these constituents varies greatly in different zones, and to a less extent in different localities.

Spheres are very abundant in the Middle Chalk, especially in the lower 50 to 80 feet, and again in the upper 40 to 50 feet. Mr. Hill's experience is that " in the lower 50 feet of the Middle Chalk Spheres are vastly more abundant than *Globigerinæ* or any other constituent except the prismatic fragments of *Inoceramus*-shell ; "

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[*] Ann. Mag. Nat. Hist., Vol. xvi., p. 75.

[†] In the "Geology of London," by W. Whitaker, Mem. Geol. Survey, Vol. i., p. 519.

[‡] Ann. Soc. Geol. du Nord, T. xix., p. 100.

[¶] Contribution à l'étude Micrographique des Terrains Sedimentaires, Lille, 1897, pp. 452–478.

and this remark applies not only to the whole of England, but to large parts of northern France also, as may be gathered from the descriptions of M. L. Cayeux. (Op. cit.)

In the Upper Chalk Spheres are abundant in the zone of *Holaster planus*, but they decrease in number through that of *Micr. cortestudinarium*. In the higher zones they are much less numerous, though generally present. Mr. Hill informs me that it is often difficult to say whether the spherical bodies one sees in a slide of chalk are really Spheres or single foraminiferal cells (see p. 501); he believes, however, that in most cases both are present. Some samples from the same zone contain a larger number than others, but he thinks that above the zone of *M. cortestudinarium* such cells and Spheres together seldom make up more than 15 per cent. of the recognisable ingredients of the chalk.

With respect to the occurrence of Spheres in recent calcareous oozes, we are unable at present to make a definite statement. Minute spherical bodies do exist in many examples of ooze, and some are figured on Plate xi. of the *Challenger Report* on Oceanic Deposits, but Mr. Hill is inclined to regard these as foraminiferal cells. and he has not seen any which quite correspond with the Spheres of the chalk.

Shell-fragments are another important constituent of some parts of the Chalk formation, and under this head we include fragments of the shells of Mollusca and Brachiopoda, of the zoaria of Bryozoa, of the tests and spines of Echinoderms, and of the ossicles of Starfish and Crinoids. Of all these organisms Lamellibranch Mollusca, and especially the genus *Inoceramus*, have contributed the largest quantity of fragments, and this is only what might have been expected from the frequency with which more or less perfect shells of that genus occur throughout the Chalk.

As in the case of Spheres, but to a still greater extent, the quantity of shell-fragments varies greatly in different parts of the Middle and Upper Chalk; at some horizons the chalk is full of them, while at others they are practically absent. In the zone of *Rhynchonella Cuvieri* they are always conspicuously abundant, and are fairly so in the lower part of the *Terebratulina* zone, but become fewer and fewer in the higher part. In the zone of *Holaster planus* they are again very numerous, but above that their numbers once more decrease till in the zone of *Micraster coranguinum* there are generally very few, though locally there are layers or bands in which such fragments are abundant. In the upper part of the *M. coranguinum* zone, and in the zones of *Marsupites* and of *Actinocamax quadratus* there are fewer shell-fragments than in any other part of the Chalk, that is to say, there are fewer fragments of the size we are now considering, and especially of *Inoceramus*-prisms. With regard to the zone of *Belemnitella mucronata*, Mr. Hill finds that in such specimens as he has examined shell-fragments are decidedly more numerous than they are in the central part of the Upper Chalk, and further, that in the Trimmingham Chalk, they are much more abundant, its apparent grittiness being due to the quantity of such fragments and of Foraminifera.

If we compare the shell-fragments of the chalk with those of recent calcareous oozes we find one conspicuous difference, and this is the absence of prismatic shell-debris. Since, however, the genus *Inoceramus* is extinct, and its nearest living representative, *Perna,* has a restricted range both in space and in depth, the absence of such fragments in modern Pteropod and Globigerina oozes is easily accounted for. Chalky oozes that are being accumulated at no great distance from land, and in less than 800 fathoms, often contain much shell-débris derived from the shells of Gasteropoda, Lamellibranchiata, Pteropoda, and Heteropoda, fragments of Echinoderm tests and spines, Bryozoa, Ostracods, and calcareous Algæ ; but in the deposits which are found in deeper water such fragments are much rarer.

Viewed as a whole, therefore, modern oceanic deposits exhibit as great differences in the quality of shell-débris which they contain as do the different portions of the great Cretaceous deposits of chalk ; but the differences observable in the Cretaceous deposits may not have been due so directly to the bathymetric conditions, because it is quite possible that many of the Cretaceous shells, such as species of *Inoceramus, Ostrea, and Spondylus,* lived in deeper water than any recent species of these genera seem to frequent.

2. Is White Chalk a Foraminiferal Deposit ?

A cursory consideration of the differences above mentioned might lead to the conclusion that very little of the chalk is really a foraminiferal deposit, and that few parts of it can be compared at all with Globigerina ooze. There are reasons, however, for thinking that we shall be greatly mistaken if we suppose that the surface layer of a calcareous oceanic ooze furnishes us with anything like a sample of the deposit as a mass ; and yet the published descriptions of these oozes relate almost entirely to this surface layer.

In the greater depths, where little calcareous material seems able to accumulate and where red clay is the prevalent deposit, it is quite possible that the lower layers do not differ much from that at the surface. But in the lesser depths, between 2,000 and 500 fathoms, where the rate of deposition is much more rapid and where there is a constant fall, or "rain," of pelagic Foraminifera and Mollusca, it is surely most probable that the lower layers differ considerably from that which lies on the surface. The very influence, supposed to be the decomposing and solvent action of sea water, which causes the disappearance of Pteropod shells at about 1,400 fathoms, and that of Foraminifera at about 2,500 fathoms, must have some effect on the constituents of the calcareous oozes. The more delicate shells in the surface layer must be the first to yield to this influence and must help to form the fine calcareous powder or paste in which the stronger shells are embedded. Thus we might naturally expect that this disintegration of the more friable shells would continue even after a given layer was covered by several inches of fresh deposit, and consequently that the aspect of the material in its lower layers would be very different from that of its surface layer.

As a matter of fact, the sounding tube of the *Challenger* apparatus did on a few occasions pierce the surface layer and brought up samples of just such a more compact deeper layer as might have been expected. Perhaps the most remarkable case of this was at Station 334 in the South Atlantic, at a depth of 1,915 fathoms, and is thus described (Op. cit., p. 143): "The sounding tube had sunk about a foot (30 cm.) into the bottom and brought up a litre of the deposit. Of this there were two layers, separated by a thin dark line, an upper layer of a light brown colour and about 8 inches (20 cm.) in thickness; and a lower, milk-white and over an inch in thickness, chiefly made up of amorphous calcareous matter and coccoliths. On analysis the upper layer gave 84·65 per cent. of carbonate of lime, the lower 85·77 per cent."

Again, at Station 331, in the same region and at a depth of 1,715 fathoms, "the tube had sunk a foot into the bottom and brought up about a quart (over a litre) of the ooze. The lower layers were more compact than the upper" (Op. cit., p. 141).* Differences between the top and the lower layers were noticed also at Station 270 (Pacific), Station 283 (Pacific), Station 296 (Pacific), and Station 330 (Atlantic).

I believe M. A. de Grossouvre was the first to point out the significance of these facts. Writing in 1892† on the conditions under which chalk has been formed, and admitting the difference between chalk and Globigerina ooze taken from the surface layer, he remarks, "in this connection, however, we should take note of the results of certain soundings, which have shown that, while the surface layer of the Globigerina ooze was formed principally of the shells and shell-debris of these organisms, the subjacent layer consisted solely of very fine calcareous mud, as if the *Globigerina* were perfect only in the upper layer and those underneath had crumbled into dust in consequence of the decomposition of the organic matter" [in their shells].

The probability of such a difference between the upper and lower layers of Globigerina ooze was independently pointed out by Professor J. B. Harrison and myself in 1895‡ when comparing some specimens of the modern ooze with Tertiary and Cretaceous chalk. We suggested that the reason why "deposits of a chalky character were not common among the *Challenger* dredgings" was that these dredgings came almost entirely from the surface-layer; and that the deeper layers might have "as close a similarity to chalk as the surface ooze has in chemical composition."

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* Wyville Thomson (Depths of the Sea, p. 409) has carefully described a dredging obtained in 1869 from the Bay of Biscay, in which the lower part consisted mainly of compact structureless chalky mud, markedly contrasting with the surface layer of Globigerina ooze.

† Ann. Soc. Geol. Nord, Vol. xx. p. 7.

‡ Quart. Journ. Geol. Soc., Vol. li., p. 328.

When, therefore, we consider that the superficial layer of Globigerina ooze is almost certainly the mere raw material out of which the mass of the underlying deposit is formed, and that in all probability this final product is not a granular ooze but a fine compact chalky mud; when also we bear in mind the Tertiary chalk of Barbados, and recollect the further alteration and consolidation which Cretaceous chalk must have undergone, we may say safely that very little force remains in the objection against the comparison of chalk and foraminiferal ooze on the score of the rarity of perfect pelagic Foraminifera in the former.

When further exploration is made of the deeper layers of the calcareous oceanic deposits, it is probable that these will be found to be quite comparable with chalk in this respect; and for present purposes, if it can be shown that in all other respects there is a close resemblance between any part of the English Chalk and recent Globigerina ooze, I see no reason why the conditions under which the latter is now being formed should not be taken as a general index of those under which the former was accumulated.

At the same time it must be distinctly understood that we are far from making the assertion that Cretaceous chalk was originally a Globigerina ooze. On this point Mr. Hill sends me the following remarks, "I agree that the chalk is largely a foraminiferal deposit, and that in this sense it may be compared with a foraminiferal ooze, such as that which is known as 'Globigerina ooze,' but I see no evidence that our chalk has ever been a Globigerina ooze in the sense that tests of *Globigerina* were its principal organic constituent." He continues,—

"If *Globigerina* was originally the dominant form, how is it that so few tests have escaped destruction as compared with those of other genera. In most parts of the Upper Chalk *Globigerina* is absolutely rare, while in the same washings other genera occur by the hundred, and though in the Middle Chalk *Globigerina* is sometimes fairly common, yet other forms are collectively more numerous. This seems inexplicable on the supposition that *Globigerina* were originally the most numerous, for such large and strong-tested forms surely had an equal chance of escaping disintegration, and even a better chance than some of the delicate forms which do occur.

"The Barbadian chalk illustrates the force of the argument, for though it is true that *Globigerinæ* are not of more frequent occurrence in it than in some parts of the English chalk, they are the only Foraminifera that are common in the rock. Moreover, their thick shells and their general resemblance to those of the modern ooze, as well as the character of the fine surrounding matrix, lead irresistibly to the conclusion that we are here dealing with an ancient Globigerina ooze. I have washed a sample of the chalk from Codrington (Barbados) and find that nine-tenths of the Foraminifera are *Globigerina,* and that in quantity there are more than treble the number of all the larger Foraminifera that would be obtained from the washing of a piece of chalk taken from the middle of the *Terebratulina* zone.

" With respect to the possible solution of *Globigerina,* my observations lead me to think that when a calcareous mud originally consisting of amorphous material and fragments of calcareous organisms and Foraminifera is undergoing a gradual change toward crystallisation, the coarse particles, such as the shell-fragments and Foraminifera, retain their identity the longest, and that it is only on the sea-floor that Foraminifera break up into unrecognisable particles. Although percolating water can and does obliterate the character of the minutest particles, the larger calcareous objects retain their shape, and even their structure, although they may be surrounded by a greatly altered matrix.

" Hence, though a secondary crystallisation has been set up in the Barbados rocks and in our own chalk after the upheaval of these deposits into dry land, yet I do not think this has had any destructive effect on the Foraminifera. It seems to me that all those which escaped destruction on the ocean-floor have been preserved, and will continue to be preserved, unless a further and more complete crystallisation of the whole rock should take place.

" Assuming, therefore, as we seem justified in doing, that in Barbados chalk we have an ancient Globigerina ooze in its massive form, as distinct from the surface layer of modern ooze, and that this has advanced as far in the process of rock-making as our own chalk, it is particularly noteworthy that it still retains the leading features of a true Globigerina ooze. Consequently, when we find that English chalk closely resembles the Barbadian chalk in most respects, but differs in this particular of the dominant organic constituent, we may reasonably infer that species of *Globigerina* did not swarm in the sea of the European chalk as they do in the larger oceans of the present day, and that our chalk is not truly a Globigerina ooze."

In this connection we should remember that even at the present time there are oceanic areas where *Globigerina* is not the dominant type. This is the case in the " deep-water cold area " of the northern part of the North Atlantic between Norway, Iceland, and Greenland, as described by Professor G. O. Sars.* Here the sea bed, at depths of from 500 to 2,000 fathoms, consists of a soft, sticky mud, of which the chief organic constituent is *Biloculina ringens.* The deposit has been called "*Biloculina* clay," but as the material when dried is said to form a "hard, light-coloured calcareous mass," it appears to be a kind of calcareous ooze. A sample from which most of the fine impalpable ooze had been removed was examined by Dr. Brady, who found the components to be as follow, stated in proportion by weight:—

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* See *Challenger* Reports, Vol. ix., p. 139 (Foraminifera).

	per cent.
Biloculina ringens (one-half being entire shells) - - -	50
Haplophragmium latidorsatum - - - - - -	20
Globigerina borealis - - - - - - - - -	4
Sand with a few other Foraminifera - - - - -	20
Impalpable *débris* - - - - - - - - -	6

It is distinctly stated that the mass of this material consists of finely divided matter, and that the *Biloculinæ* do not amount to more than 2 per cubic centimetre.

To sum up, therefore, we believe that the white chalk of England and France is a deep-sea foraminiferal deposit comparable with *Biloculina* ooze and with the lower layers of Globigerina ooze, but not identical with either. We believe that the disintegration of the organisms which have furnished the material of the calcareous matrix was accomplished beneath the floor of the Cretaceous sea, and that several kinds of organisms have contributed to its formation, one predominating at one time and one at another. Among these, Spheres and shell-fragments are frequently as numerous as the tests of Foraminifera.

CHAPTER XLVI.

THE PHYSICAL AND GEOGRAPHICAL CONDITIONS OF THE MIDDLE CHALK PERIOD.

Geographical Conditions.

Our conception of the geography of the Anglo-Gallic region during the formation of the Middle Chalk must be based mainly on the conclusions at which we have previously arrived respecting the relative positions of sea and land in the Lower Chalk or Cenomanian period. Owing to subsequent detrition and denudation there are very few places in the British Isles where the Middle Chalk shows any sign of near approach to land. In England there are no such places, and we can only infer, from the purely calcareous character of the chalk of which this part of the formation consists, that it was formed during the progress of a continued subsidence, whereby the area of the neighbouring lands was still further reduced and their coast-lines were still further removed from the central portions of the sea.

In France, however, there are much greater differences in the lithological characters of the deposits which correspond with our Middle Chalk. Thus in the north-east of France (Nord, Aisne, and Ardennes) the deposits of this age are argillaceous marls and marly clays, which sometimes contain as much as 70 per cent. of clay, and are clearly terrigenous deposits; they attest the continued existence of land in the south of Belgium and the country of the Rhine.

In the central and south-eastern parts of the Paris basin the beds present a deep-water chalky facies closely resembling that of southern England, and this facies extends as far west as the neighbourhood of Rouen and Fécamp.

In the western part of the basin, however, in the departments of Calvados, Orne, and Sarthe, and in the valley of the Loire, the Lower Turonian chalk passes into a soft marl containing 15 or 16 per cent. of clay, a deposit resembling our "Chalk Marl," and doubtless formed under similar conditions. Moreover, the higher beds in the south-west (*Angoumien*) are not chalks at all, but siliceous and quartzose limestones, with some calcareous sands.*

The varying lithological aspects of the Turonian and Senonian deposits in France are shown in a tabular view by M. Cayeux

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*See Contribution à l étude Micrographique des Terrains Sédimentaires, par L. Cayeux, p. 405, Lille, 1897.

(Op. cit., p. 470), and for this purpose he proposes a special classification of these sediments. Some are terrigenous in the sense indicated by Messrs. Murray and Renard, and some are truly pelagic, but, as he points out, there are others which contain little terrigenous material, and which yet cannot be called pelagic, such, for instance, as beds which are largely composed of Bryozoa, or of the remains of siliceous sponges; for these he proposes the term "*benthogene*," which might be translated as *benthal.*[*]

Using these terms, he tabulates the varying characters of the Turonian sediments of the Paris basin in the following manner:—

Zones.	Gulf of Mons.	Nord.	Centre.	South-west.
M. breviporus	Pelagic	Terrigene.	Pelagic.	Terrigene
Ter. gracilis	Pelagic			Terrigene and benthogene.
In. labiatus (=Rh. Cuvieri).	Benthogene or terrigene.			Pelagic or benthogene.

In England the only Turonian deposit which might be called *benthogene* or *benthal* is the Beer Stone of Devon (see p. 506).

If, then, there was land to the east and to the west of the Paris basin, and also, as is most probable, to the south over Central France, in what directions are we to look for possible openings and for connections between the Anglo-Parisian sea and the larger seas or oceans of the period?

It is well known that the Chalk, and especially the Middle and Upper divisions of the formation, occupy very large areas in central and eastern Europe. There can be no doubt that a broad sea spread eastward at this period from England through Belgium, Holland, Denmark, and Germany into Central and Southern Russia. There was also another sea in Southern Europe, the deposits of which are found in the Alpine region, and it is not improbable that this communicated with the more northern sea round both ends of a Central European island. The western end of this island and the connection of these two seas has been shown in a map drawn by Dr. W F. Hume to illustrate his paper on the "Genesis of the Chalk."[†] Another broad sea-space existed in the south of France, which is sometimes termed the Hippurite Sea by French geologists.

The evidence for the communication between these seas and that of the Paris basin has been discussed by M. Cayeux in the work already quoted (p. 561). He considers it certain that there was a wide and deep opening to the south across the region of the Cote d'Or. He says: "The existence of Micrasters in flints at several places on the Morvan [Niévre] shows that the chalk was deposited over at least a part of this region, and that it has been removed by denudation. But were such testimony absent the same inference might be deduced from the great purity of the chalk along the south-eastern border, for it is in this part of the Paris basin that the formation best maintains its character of a pelagic deposit. We must admit the existence, not of a mere strait, but of a communication as wide as the whole region which now separates the Vosges from Morvan. Some patches of white chalk have been found at the foot of the Chalonnais slope, their preservation being due to faults. . . . White chalk, with *Echinoconus conicus* and *Micrasters*, has been found near Lains (canton de Lons-le-Saulnier, Jura) at a height of 520 metres (1,700 feet), and even further south on the line of the Alpine chain. Our knowledge of the Cretaceous strata of Savoy, of Dauphiné, of Haute Provence, and of the Alps affords abundant proof that it was in this direction that the Cretaceous Sea was prolonged, and not down the valley of the Rhone."*

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[*] The term *benthal* has been used by Gwyn Jeffreys in a rather different sense, for he applied it to deep-sea (pelagic) deposits. It would be more useful if employed in the sense suggested by M. Cayeux for deposits which are neither terrigenous nor pelagic.

[†] Proc. Geol. Assoc., Vol. xiii. p. 211 (1894)

That a communication existed between the south-eastern part of the Paris basin and the Aquitanian region is also accepted by M. Cayeux, who speaks of it as the Strait of Poitou, and considers that it was by this passage that some of the *Rudistæ* of the Hippurite Sea gained access to the more northern parts of the Turonian Sea (Op. cit. p. 599.)†

It is clear, therefore, that there is plenty of evidence for communications with eastern and southern seas; it remains for us to consider the possibility of westward openings into an Atlantic Ocean. In the first place, we have no assurance that any such ocean existed in the Cretaceous period. Those who believe in the permanence of oceans and continents consider, of course, that there was always an Atlantic Ocean from the earliest times to the present day, but this belief is founded upon theoretical conceptions of the manner in which the consolidation of the earth has been accomplished, and is not accepted by all geologists. My own belief is that the oceanic depressions and the continental plateaux have been gradually developed through a long series of geographical mutations, ‡ and that their present aspect is probably widely different from that which they presented in the Cretaceous period.

Inasmuch as the greater part of Europe was unquestionably not continental land in Turonian and Senonian times, but was the site of a large sea or small ocean, studded with islands, it may be argued that by analogy the distribution of land and water in the Atlantic area may have been equally different at that period. This argument may, indeed, be carried still further, and may be used in favour of a presumption that there was both land and sea within the area of the North Atlantic. For what we know of the range and extent of the Chalk formation as a whole in Europe suggests that the general trend of the larger land and sea areas was from east to west, and it is not improbable that this east and west trend was prevalent at that time throughout the whole of the northern hemisphere. The Upper Cretaceous Ocean may have had a wide extension across both the Atlantic and European regions between the parallels of 30 and 50 degrees N. Lat. while the larger continental areas lay to the north and south of these parallels, and more especially to the northward.

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*He holds that Dr. Hume's sketch-map was incorrect in showing a gulf running southward down the valley of the Rhone, but I see no reason why there should not have been an opening southward into the Hippurite Sea, as well as eastward into the Alpine Sea. The land in central France may have been an island.

† See also de Grossouvre "Sur le Detroit de Poitiers," in Comptes-ren dus de l'Assoc. Franc. pour l'Adv. des Sciences, 1901, p. 398.

‡ See Building of the British Isles, Second Edition, Chapter xvi. (1892).

I am, therefore, quite ready to admit that there are theoretical grounds for assuming the existence of a large sea-space or ocean within the area of the North Atlantic during the Upper Cretaceous period; but I see no evidence for supposing that it bore any resemblance in shape, direction, or depth to the modern Atlantic.

Our present concern with this possible Atlantic sea is to consider the probable location of the openings which may have connected it with the European sea. The first and most obvious westward opening is that of the Aquitanian and Pyrenean region. The present coast of France cuts apparently through the very centre of this basin, out of which the Atlantic has eaten the great bay which we call the Bay of Biscay, and the French term the Gulf of Gascony. It is necessary, however, to point out that the Turonian deposits in the south of France do not present a deep water facies like that of the Paris basin; they consist chiefly of marls or shelly or sub-oolitic limestones, with some sandy beds, and the most conspicuous fossils in the calcareous beds are the thick-shelled *Hippurites* and other members of the Rudistean family. Thus, unless there was good evidence to the contrary, we might imagine that the Turonian sea of the Aquitanian period was a dependence of the Mediterranean, and not of the Atlantic, being only a gulf or embayment on the border of the western Continent.

French geologists, however, have always believed that this Aquitanian sea opened westward into an Atlantic Ocean, and M. Ph. Glangeaud, of Clermont-Ferrand, has been kind enough to acquaint me with some of the facts on which this belief is based. It appears that in the northern part of the basin (the Charentes and Dordogne) the lower part of the Turonian consists everywhere of marly limestones with *Ammonites*, and it is inferred that the water was fairly deep and that there was open communication with the northern sea through the straits of Poitou. The higher part of the Turonian exhibits more differentiation, and in Dordogne, south of Périgueux, there are detrital deposits of this age, while to the north-west limestones with *Rudistæ* were being formed. Again in the southern part of the basin there are limestones with *Ammonites* at Roquefort in the west, while in the Corbières, on the east, there are sandstones both at the base and the top of the formation, with Rudistean limestones in the middle. M. Glangeaud is therefore of opinion that there was a deep and open sea to the westward, and that at the close of the Turonian age the openings both into the northern and the Mediterranean seas were narrow and shallow.

Passing now to the northward, there is in the first place every reason to believe that Brittany was united to Cornwall in Turonian time, as it was in the Cenomanian, and that no westward opening existed along the line of the English Channel at any epoch of Cretaceous time. I argued for this view in 1892,* and am pleased to find that M. Cayeux is of the same opinion. He remarks (Op. cit., p. 560):—"I do not know of any fact which would favour the existence of a strait connecting the Anglo-Parisian sea with the ocean on the site of the English Channel; on the contrary, I see several objections to such a view." He mentions the rapid thinning of the Turonian series westward from Fécamp, but does not refer to a fact which seems still more conclusive, namely, the small Cretaceous outlier in the Cotentin, where chalky limestone, with Senonian fossils, rests upon sands which are generally supposed to be of Cenomanian age, but might possibly be Lower Turonian; in either case there is a complete absence of any Turonian *chalk*.

Coming now to England, we find in Devonshire evidence that at the beginning of Turonian time the coast-line was still not far distant and that the water was not very deep. The Beer stone is not a chalk but a shell-sand, and its residue contains a variety of minerals which have clearly been derived from land consisting of Granite and Palæozoic rocks such as occur in South Devon and Cornwall. It is equally clear, however, that a considerable subsidence ensued, for not only does the chalk of the Terebratulina zone in Devon resemble that of more eastern counties, but it is actually thicker than in Dorset or Wiltshire. Such a thickness of pure chalk (90 to 100 ft.) seems to indicate that the depth of water had increased and that the shore-line had receded to some extent.

We are therefore at liberty to speculate upon the possibility of the western land being so lowered and broken up that, if there was an Atlantic sea beyond, a communication with it may have been opened up across the north of Devon and across the Irish Sea. At the same time, it must be admitted that such an idea must remain a pure speculatiōn; there is no positive evidence for it—merely the fact that in East Devonshire we find no trace of a shore line for the Turonian Sea. Moreover, the land may have risen steeply from the sea, and the subsidence may have greatly lessened its height without much diminishing its area; consequently, in constructing the hypothetical map (Fig. 87), I have assumed that the western land was not very different from what it had been in Cenomanian time.

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* The Geographical Evolution of the English Channel, Contemporary Review, Vol. lxi. p. 855 (1891).

Farther northward, however, in the north-east of Ireland, we have positive evidence of the shallowing of the British Turonian sea toward the west. It is uncertain how much of the Irish Cretaceous series corresponds with the Middle Chalk of England, and it may indeed be doubted whether any of it does. Between the beds which are undoubtedly of upper Chalk age (containing *Echinocorys gibbus*) and those which are certainly Cenomanian there is a great break and plane of erosion throughout Antrim. There is nothing which can be compared with the English zone of *Rhynchonella Cuvieri*, but Professor Barrois* thought that a certain group of glauconitic sands and sandstone containing *Exogyra columba* was the equivalent of the zones of *Terebratulina gracilis* and *Holaster planus*. Dr. W. F. Hume,† however, is doubtful about this correlation, and appears to think that in most of the sections there is a great break between the Cenomanian and the Senonian (Upper Chalk), and that there is very little which can possibly represent the zones of *Rh. Cuvieri, Ter. gracilis,* or *Hol. planus.* He admits, however, that the highest part of the *Exogyra columba* sands may belong to the Middle Chalk, and that the *Inoceramus* beds may be partly equivalent to the Chalk Rock.

It is clear, therefore, that if any Turonian exists in Antrim, it has the character of a glauconite sand, and that the base of the Upper Chalk is also a sandstone or sandy limestone; hence there can be no doubt that the Turonian sea was there decidedly shallow, that land was not far off, and that strong currents prevented the deposition of much sediment in that area throughout the whole epoch of the Middle Chalk.

Both Professor Barrois and M. Cayeux have regarded the Cretaceous deposits of Ireland and Western Scotland as having been formed in a gulf which opened out of the British sea, but had no connection with the Atlantic Ocean. M. Cayeux, however, suggests that the main communication between the Cretaceous North Sea and the Atlantic was round the northern extremity of the British Isles. It is true that the large quantity of flints occurring in the surface deposits of eastern Scotland proves that the Cretaceous sea extended for a considerable distance to the northward, but this is hardly sufficient evidence on which to base such a theory. It is a possible view, and that is all that can be said for it.

In conclusion, I would point out that the evidence in favour of free and open communication between the Anglo-Parisian Sea and the more eastern seas existing in Turonian time is very strong, while the only direction in which there is any good reason for supposing a direct communication between this sea and a western ocean is through Poitou and the Charentes, toward the region of the central Atlantic. This view is represented in the sketch-map (Fig. 86). So far as we can see, the geography of the western land

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* Recherches sur le Terrain crétacé de l'Angleterre et de l'Island, p. 214.

† Quart. Journ. Geol. Soc., Vol. liii. pp. 591 and 598.

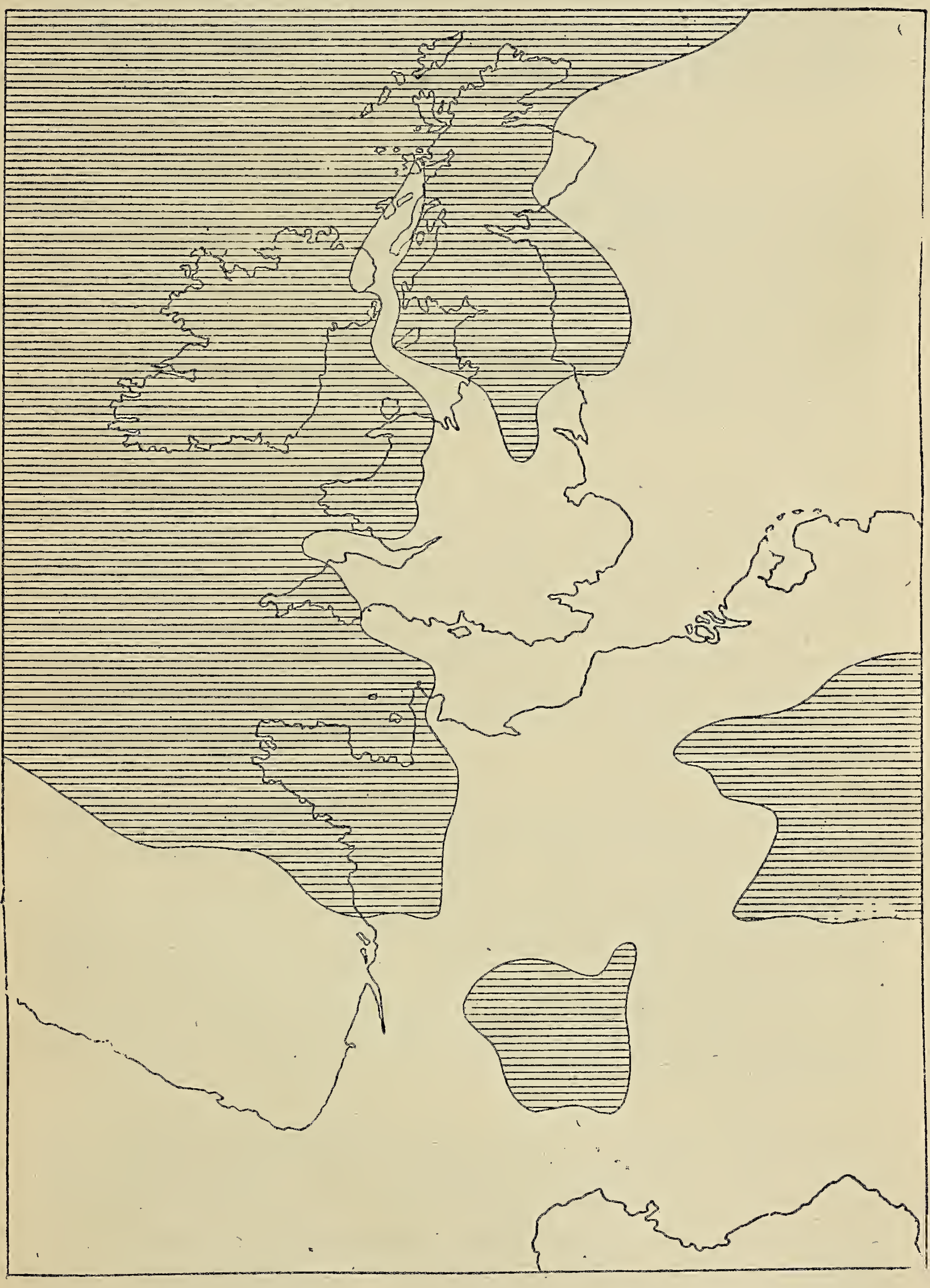

Fig. 87.—Hypothetical restoration of the Geography of the British and French regions during the age of the Middle Chalk (Turonian). The barred spaces represent land,

during the formation of our Middle Chalk was not very different from that which existed during the time of the Lower Chalk. This may be accounted for in two ways: either the movement of subsidence was much less in the Atlantic region than in the European, or, if the subsidence was of nearly equal amount in both regions, the western land was so much higher and steeper that only small parts of it were actually submerged by a depression which carried the sea over large parts of the European land.

Evidence of Current-Action.

The Middle Chalk nearly everywhere presents clear indications of the action of strong currents, and not only of surface currents, but also at one time of currents that swept over the floor of the sea. Some alteration in the strength and direction of the marine currents may very probably have been produced by the opening or deepening of the straits of Poitou, between Brittany and the Plateau of Central France, which thus probably became an island.

The evidence for the bottom current above mentioned is found in the nodular character of the Melbourn Rock, and in the nodular structure of nearly the whole of the Middle Chalk in South and West Dorset. In Lincolnshire also the whole zone of *Rhynchonella Cuvieri* is of a nature that suggests the action of a strong current, for it is condensed into a small thickness, consists of rough shelly and nodular chalk, and terminates in a layer of shaly marl, which marks it off sharply from the pure white, fine-grained chalk of the overlying zone.

All who have discussed the nodular structure of these beds agree in regarding it as due to slow accumulation under the influence of a strong current. Thus, describing the Melbourn Rock in 1886, Mr. Hill and I wrote as follows:—"It may also be noticed that the atoms of shell are sometimes arranged round the nodule in a manner which suggests either the gradual sinking of the nodule into the soft mud, or that the atoms of shell were deflected from their course by the nodule, while travelling over the sea-bed under the action of a current."*

Dr. W. F. Hume, writing in 1894, explained the nodular condition of the *Rhynchonella Cuvieri* zone as "directly due to the currents set up by the sudden alteration in physical conditions," and inferred that "most chalky nodular beds are thus formed, whether under the influence of elevation or depression."†

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* Quart. Journ. Geol. Soc., Vol. xlii., p. 230.
† Proc. Geol. Assoc., Vol. xiii., p. 230.

In a still more recent volume* M. L. Cayeux, though not inclined to regard such nodular structure in chalk as always the result of contemporaneous current-action, remarks that "the nodular structure of the *Inoceramus labiatus* zone is that which has the greatest resemblance to the conglomerate of Station 196 (*Challenger* Expedition). The study of this chalk has led me to the conclusion that its peculiar texture cannot be explained without admitting a strong dynamic action operating on the sea-floor at the very time of its accumulation."

The conglomerate referred to by M. Cayeux is described on pp. 99 and 171 of the *Challenger* Report on Deep Sea Deposits. It was found on hard ground at a depth of 825 fathoms, the trawl bringing up large "irregular fragments of a honeycombed conglomerate, overgrown with Serpula, Polyzoa, and Sponges. . . The sections showed that the conglomerate was composed of Foraminifera and calcareous Algæ, cemented together into a hard crystalline limestone." Although, as Sir J. Murray observes, "this rock would seem to have been formed in comparatively shallow water near land;" the occurrence is important, as indicating a hard, bare, current-swept floor at a depth of 825 fathoms.

At another locality, moreover, the *Challenger* seems to have found a really nodular and indurated Globigerina ooze. This was at Station 192A, off the Ke Islands, west of New Guinea. Here the bottom at 140 fathoms was blue mud, but from 129 fathoms the trawl brought up many rounded nodules of very hard, calcareous rock, consisting entirely of the shells of *Globigerina*, *Pulvinulina*, and *Orbulina*, in a calcareous matrix, and containing 79·56 per cent. of carbonate of lime. It is suggested that these concretions "are hardened portions of a deep-sea deposit, formed at a much greater depth, and subsequently elevated into the position in which they are now found." (Op. cit., p. 171.)

The occurrence of "rounded, compact chalky nodules apparently formed of the deposit" is recorded at Station 44, the deposit being described as "blue mud" with 24·61 per cent. of calcium carbonate, depth 1,700 fathoms. Again, at Station 191A, near the Arron Islands, at a depth of 580 fathoms the green mud, with 40 per cent. of calcium carbonate, contained "some concretions of Globigerina ooze cemented into a fine, almost opaque paste of carbonate of lime." (Op. cit., p. 95). A chalky Pteropod ooze containing "hard chalky concretions" was found by the American *Blake* Expedition near Cuba in 860 fathoms.

Hard ground, presumably swept clear of deposit by bottom currents, was found at various depths by the *Challenger* Expedition, as, for instance, between 325 and 950 fathoms off the Spanish coast; off Tristan d'Acunha, at depths of 550, 1,000, and 1,100 fathoms; and in the Molucca passage as above stated. Mr. Stallibrass has recorded the existence of strong currents between the Canary Islands at a depth of 1,000 fathoms.*

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* Contribution à l'étude Micrographique des Terrains Sédimentaires, p. 557 (1897).

Returning to the current phenomena of the Middle Chalk, the existence of surface currents is indicated by the occasional occurrence of drift wood, and of transported stones and blocks of rock, and, so far, these have occurred chiefly in the south-eastern counties. The layers of grey marl and marly clay again, which occur as thin seams between the thick beds of pure chalk, are additional evidences. I think both these phenomena may be attributed to seasons of heavy rainfall, producing periodic land floods, whereby an unusual quantity of fine muddy detritus and soil was poured into the sea from off the neighbouring lands, and was carried to great distances by the surface currents.

There is another peculiarity of the Middle Chalk which may possibly have a direct relation to currents, either at the surface or along the bottom. This is the abundance of fish remains, and here, again, we find such remains especially frequent in the south-eastern counties. Dr. Hume was, I believe, the first to suggest a connection between currents and fish remains. Writing of the Lewes and Brighton district, he remarks, "a further point to note is the abundant fish fauna of this district. Why is this? The answer, perhaps, is not far to seek. The current will evidently carry along with it large amounts of [food] material derived from the littoral area, and far more suitable to a piscine palate than the usual minute pelagic fauna of an oceanic region. The result would be that comparatively shallow water Teleostean fishes, such as *Beryx*, would have their range greatly extended seawards, while the rich increase in food material would tend to bring together large numbers of predatory fishes, especially sharks such as *Lamna*."

BATHYMETRICAL CONDITIONS.

Coming now to the consideration of the depth of water below which our Middle Chalk may have been accumulated, we must bear in mind the inferences already indicated under the head of geographical conditions, and must remember that there were tracts of land both to the west and the east, as well as to the south, of the Anglo-Gallic sea. Consequently, this sea was not an open ocean, and no part of the Middle Chalk is likely to have been deposited in very deep water nor very far from land. By this I mean that the water is not likely to have been anywhere over 1,000 fathoms in depth, and that the central part of the sea was not more than 200 or 250 miles from the nearest land.

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* Journ. Soc. Tel. Eng., 1887.

At the same time, the purity of the chalk of this stage is very great, and the seams of marl which do occur are very thin; whence we must infer that very little terrigenous material was, as a rule, carried into the Turonian Sea. This purity of the deposit may have been due to several causes. We know that the region was undergoing subsidence, a process which checks detrition and leads to the drowning of river valleys, and their conversion into fiords or lochs, with the consequence that less sediment is carried into the open sea. Again, the nearest tracts of land appear to have been of the nature of islands or of promontories, and, consequently, were not likely to produce any large rivers. Lastly, though there seems to have been a large area of land to the west of Great Britain, it is quite possible that the main drainage of this land was directed westward or southward, so that no mud-bearing rivers emptied themselves through its eastern shores.

It is fairly certain also that the area in which the Middle Chalk of England was accumulated was part of the deeper and more central portion of the Anglo-Parisian sea; but the attempt to form some idea of the actual depth of this part of the sea is beset with difficulties. It is fairly safe to say that it was deeper than it had ever been during the epoch of the Lower Chalk, but a subsidence of 100 feet may have been sufficient to submerge much land and ensure the formation of a purer kind of deposit, and 100 feet is less than 17 fathoms.

In attacking this problem we can, of course, only argue by analogy, and cannot hope to find any certain criterion. As in other cases, there are two sets of facts, which provide us with a certain amount of evidence—(1) microscopical inquiry into the relative quantities and dimensions of the detrital minerals found in the chalk and the ooze; (2) the included organisms and the analogies which they suggest.

Mr. Hill has dealt with the mineral particles which exist in this part of the Chalk in Chapter xliii., to which the reader is referred, but attention may here be directed to certain points. First it is noteworthy that the total amount of extraneous mineral matter in these chalks is exceedingly small (see tables on pp. 513 and 519), and, of course, the quantity of recognisable mineral particles is still smaller. Thus, in no specimen of the *Rhynchonella Cuvieri* zone (including the Melbourn Rock) does the entire "coarse residue" exceed ·06 per cent., except in the Beer Stone and at Hitchin, where the samples contain silicified shell-fragments. In the *Terebratulina* zone the coarse residues examined by him average about ·013 per cent., except where a sample happens to include a lump of iron-oxide, as in that from Hessle (Yorkshire). The average percentages of fine insoluble residue for these zones are :—

In zone of *Rh. Cuvieri*, ·02 per cent.
In the *Terebratulina* zone, ·013 per cent.

Of the deposits explored by the *Challenger* Expedition and described by Sir J. Murray those which come nearest to such chalk are the Pteropod and Globigerina oozes between Tristan da Cunha and Ascension Island in the South Atlantic; these came from depths of between 1,415 and 2,025 fathoms, and the proportion of mineral debris was in no case more than 1 per cent. Eliminating two cases in which the quantity of deposit obtained was too small for reliable results, the remaining seven furnish the following average composition :—

Proportion of Calcareous Matter.	Proportion of Mineral Particles.	Average size of Mineral Particles.	Proportion of Fine Washings.
92·66	0·93	0·06	5·42

The proportion of fine washings varied from 2 to 12 per cent., but generally included debris of siliceous organisms which, being soluble, would be eliminated from the rock mass when the deposit was raised above the sea level. Consequently if this ooze were ever to become consolidated as a terrestrial rock, the proportion of chalky matter would be raised to 96 or 97 per cent.

The quantity of included mineral particles varies in different places and is naturally great in the neighbourhood of active volcanoes or where the prevalent winds blow off tracts of sandy desert. In most of the other Pteropod oozes the proportion of mineral particles was only 1 or 2 per cent., but the fine washings average 19 per cent. It is interesting to note the entire absence from the chalk of particles of volcanic ejectamenta, and we may safely infer that there were no volcanoes on the land areas adjacent to the Anglo-Parisian Sea.

With regard to the size of the mineral particles in the Middle Chalk, Mr. Hill finds that in ten samples of the *Rh. Cuvieri* zone the average size is only ·13 mm. though occasional fragments as large as ·4 or ·5 mm. occur. In the *Terebratulina* zone they seldom exceed ·3 mm., and the average size is only ·09 mm.

In oceanic deposits the dimensions of such particles are also variable, and the range of size is not very different from the above. The following particulars are taken from those given in the Report on Deep Sea Deposits :—

Mineral Particles in	Range of size.	Average size.
	mm.	mm.
Globigerina oozes - - - - -	·06 to ·8	·089
Pteropod oozes - - - - -	·06 to ·1	·08
Green muds - - - - -	·06 to ·2	·13
Coral muds - - - - -	very small	·07
Blue muds - - - - -	·06 to ·3	·115

It would seem, therefore, that no reference as to depth can be drawn from a consideration of the mineral particles found in the Middle Chalk. The only inferences deducible are that it was formed in clear water of some depth at a considerable distance from land and in a region where there were no volcanoes.

Let us now see if the organic contents of this division can give us more definite indications. In the first place, we must point out that the fauna is rather a small one, and that for some reason or other the conditions were not at this time very favourable to animal life, but this very scarcity of fossils may in itself be significant. We will refer to the different classes of animals separately.

Fish.—Little can be learned from the remains of fish; the commonest are those of sharks, which range all over the oceans, and are found in all kinds of deposits. Even Teleosteans, like the flat-fish which live on the bottom, have a great range in depth, some species being found below 1,000 fathoms, but Dr. Smith-Woodward remarks that "the Teleostean fish of the Chalk do not appear to have lived in very deep water, for the skeleton is always more robust than that of the true deep-water fish."* A possible explanation of the presence of such fish in the Middle Chalk has, however, been suggested by Dr. Hume, that they followed food carried out by a current setting from the shore.†

Mollusca.—The Molluscan fauna is noteworthy because it consists almost entirely of *Brachiopoda, Lamellibranchiata* and a few *Cephalopoda.* Of *Gasteropoda* only two or three genera have been found, and of these only *Solariella* and *Pleurotomaria* are widely distributed.

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*Quoted by Cayeux in Contribution à l'étude Micrographique, p. 500.

† Proc. Geol. Assoc., vol. xiii., p. 233.

The rarity of *Gasteropoda* might seem to indicate that the water was fairly deep, for at the present day they are most abundant in shallow water, and in depths of less than 500 fathoms; still there are many genera, such as *Buccinum, Fusus, Trophon, Scalaria, Chemnitzia, Cerithiopsis, Natica, Solarium, Turbo, Trochus,*and *Emarginula,* which range below 1,000 fathoms, and a few even below 2,000 fathoms. Most of these certainly existed in the Cretaceous period, since they occur in the Gault, and we cannot account for their absence in Middle Chalk by supposing that they have been destroyed since its upheaval, for in that case their casts would remain as they do in the Lower Chalk and in the Chalk Rock.

The absence of the phytophagous genera could hardly be due to the want of vegetable food on which to support existence, because modern deep sea species are supposed to feed on the pelagic algæ, which fall from the surface waters, and on the plant remains which are floated out from the land by currents. There is no reason to suppose that either of these sources of food was wanting in the waters of the Middle Chalk.

The few casts that do occur show that Gasteropods did exist, and we can only suppose that the shells were easily destroyed by solvents, and that most of such as existed were disintegrated during the formation of the chalk, just as Pteropod and Heteropod shells are disintegrated now at depths of more than 1,000 fathoms.

Of *Lamellibranchs,* the commonest belong to the genera *Ostrea, Neithea, Spondylus,* and *Inoceramus.* The last is extinct, and in modern seas the two first do not range beyond 300 fathoms, but *Spondylus* goes to 640. There is again a remarkable absence of those genera which are now characteristic of greater depths, but it is possible that such shells were actually present on the sea-floor while the material of the Middle Chalk was in process of formation, and that they were so thin and perishable that they soon fell to pieces and went to increase the bulk of the chalky mud itself.

Brachiopoda are as a rule the commonest fossils in the Middle Chalk, *Rhynchonella Cuvieri* and *Terebratulina lata* being often present in large numbers, and as they belong to types which have not undergone much change, their value for comparison with modern species is greater. The principal genera are *Rhynchonella,* *Terebratula, Terebratulina* and *Crania.* Of these the first two now range down to 2,000 fathoms, but are most abundant beyond 500 fathoms. Of *Terebratulinæ, T. caput-serpentis,* which so closely resembles the Cretaceous species *T. striata,* ranges from 0 to 1,180 fathoms, and *T. Cailleti* (which may be compared with *T. lata*) ranges to nearly 500 fathoms. *Crania* is found in all depths between 0 and 1,500 fathoms.

M. Œhlert remarks that of those which range beyond 500 metres (270 fathoms) the greater number are found between the depths of 500 and 1,500 metres (270 to 820 fathoms); these include six species of *Terebratulina,* six of *Terebratula* and *Magellania,* three of *Megerlia,* two of *Rhynchonella,* and one of *Crania.** This would indicate an average depth of 540 fathoms for the *Brachiopods* of the Middle Chalk.

Bryozoa.—Remains of these creatures are rarer in the Middle Chalk than in any other part of the formation. There are a few encrusting forms, and *Homœosolen* occurs sometimes in the zone of *Terebratulina* but other arborescent forms are very rarely found. At the present day these arborescent forms are decidedly most abundant in comparatively shallow water (50 to 150 fathoms). Some species, however, of both orders range down to 500 fathoms, and a few as far as 1,000. The rarity of *Bryozoa* in this part of the Chalk is consequently very suggestive of a greater depth than 500 fathoms.

Crustacea.—These are very rare fossils in the Middle Chalk, and as at the present day the *Decapods* range down to great depths, some *Brachyura* to 800 fathoms, and some *Macrura* to 1,500 fathoms and more, there must have been some special conditions that were unfavourable to Crustacean life. Possibly there was a deficiency of the right kind of food.

Echinodermata.—*Echinoidea* are fairly common fossils in the Middle Chalk, but only three of the genera survive to the present day—namely *Cidaris, Salenia,* and *Hemiaster.* Of these *Cidaris* (proper) does not range beyond 200 fathoms, but as *Dorocidaris* it extends to 870, *Salenia* ranges to 1,800 and *Hemiaster* to 800 fathoms. Of *Micrasters* there are two species in these beds, and the commonest is *M. corbovis,* a form which, as Dr. Gregory has pointed out to me, in its thin test and shallow-petalled ambulacra presents the aspect of a deeper sea species when contrasted with the forms in the lower zones of the Upper Chalk. *Galerites* is closely allied to the modern deep water genus *Cystechinus*, and as there is an absence of specially littoral genera, the Echinoderm fauna of the Middle Chalk has the aspect of a fairly deep water assemblage.

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* In Fischer's Manuel de Conchyhologie, p. 1252.

Spongida.—Siliceous sponges are common in the Middle Chalk, especially in that of the southern counties, and they belong chiefly to the Hexactinellids, the commonest genera being *Craticularia, Guettardia, Plocoscyphia, Cephalites* and *Ventriculites.* Dr. Rowe remarks that sponges of these and other genera are more abundant in the *Terebratulina* zone at Dover than in any other part of the Chalk, or in any other exposure of this zone known to him.* They also reach a large size in this zone, one *Guettardia* which he measured being 14 inches across, and a mass of *Craticularia Fittoni* was a foot square.

Hexactinellids are essentially deep-water sponges, and in modern seas they appear to be most abundant in depths of 300 and 1,000 fathoms.

Foraminifera.—The foraminiferal fauna of the Middle Chalk has not yet been studied in much detail, but it needs only a brief examination of a few samples to discover that the tests of arenaceous Foraminifera are much less common than in the Lower Chalk. As stated on p. 287, in the Chalk Marl fine specimens of *Textularia, Tritaxia, Gaudryina, Bulimina, Bolivina,* and other arenaceous genera are abundant; but in the higher beds they become much rarer. This was first pointed out by Dr. W. F. Hume, and with regard to the Middle Chalk he wrote, "in the lower zones of the Middle Chalk all the more coarsely-tested forms have entirely disappeared, and only the minutest Bulimines, a most delicate little *Textularia,* and the ammonitoid shells of *Ammodiscus incertus,* survive to represent the arenaceous species." †

Mr. Chapman's determinations of the species in the numerous washings and residues of Middle Chalk prepared by Mr. Hill, furnish a longer list of species, but still it is a short one compared with that of the Lower Chalk species, and it supports Dr. Hume's main contention for the arenaceous forms are chiefly species of *Ammodiscus* with small Bulimines and Textularians.

In the zone of *Rhynchonella Cuvieri* eighteen species have been identified belonging to genera which live on the sea-floor. Of these two are extinct and of the remainder no less than twelve are species which now range to depths of more than 1,000 fathoms. Only four species have been found which now have a limited range; these are *Rhizammina indivisa,* which has not occurred below 540 fathoms, *Gaudryina filiformis,* which ranges to 620 fathoms ; *Textularia trochus* and *T. turris,* which have not been obtained below 440 fathoms. All these, however, are rare species in the zone of *Rhynch. Cuvieri.*

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*See Proc. Geol. Assoc. Vol. xvi., p. 317 (1900).

† Natural Science, Vol. vii., p. 273.

Among the specimens obtained by Mr. Hill from the *Terebratulina* zone, Mr. Chapman found twenty-eight which could be specifically named. Of these six are not known as recent species, thirteen have a great range in depth, three are species of *Globigerinæ,* and there remain only six to connect the fauna with that of shallower water. These are :—

Rhizammina indivisa.
Textularia trochus.
„ turris.
Tritaxia tricarinata.
Gaudryina filiformis.
„ rugosa.

In this zone *Rotalia soldani* (var. *nitida*) and a species of *Pulvinulina* occur, and these are deep water forms.

From the above analysis it would certainly appear that the foraminiferal fauna of the Middle Chalk, when compared with that of the Lower and even with the higher part of the Lower Chalk, suggests water of a greater depth. This inference is supported by the character of the Echinoderm fauna, by the scarcity of *Bryozoa* and by the abundance of *Brachiopoda* and Siliceous Sponges. Hence, if the depth at which the Chalk Marl was formed approximated to 400 fathoms, and that of the higher beds of the Lower Chalk to 500 fathoms, it is very probable that during part of the Middle Chalk time the depth exceeded 500 fathoms ; but as we shall see hereafter there seems to have been a recovery by upheaval during the formation of the Chalk rock (zone of *Holaster planus*), consequently the time of greatest depth was probably that when the lower part of the *Terebratulina* zone was being accumulated.

	ZONES.	SOUTH-WEST AREA (DORSET).	SOUTH-EAST AREA (KENT AND SUSSEX).
MIDDLE CHALK.	Terebratulina zone.	Nodular chalk with a layer of green-coated nodules at base; *Holaster planus.*	Nodular and smooth chalk with *Holaster planus.*
		Smooth white chalk with occasional flints; *Ter. lata.*, and *Inoc. Cuvieri.*	Soft white chalk with a few flints (in Kent) and seams of greyish marl; *Ter. lata, Inoc. Cuvieri* and *Gal. subrotundus.*
	Rhynchonella Cuvieri.	Rough nodular chalk with harder beds at the base; *Inoc. mytiloides* and *Rhynch Cuvieri.* Hard smooth white chalk from 6 to 22 feet thick; few fossils.	Massive chalk with layers of nodules passing down into hard nodular chalk (20 to 30 feet) representing the Melbourn Rock; *Inoc. mytiloides, Cardiaster pygmæus* and *Am. nodosoides.*
	Thickness- -	From 100 to 134 feet.	From 214 to 230 feet.
LOWER CHALK.	Holaster subglobosus.	Soft grey marl (thick).	Soft grey marl (thick) with. *Act. planus.*
		White chalk with layers of grey marl, *Am. navicularis.*	White chalk with *Discoidea cylindrica* and *Hol. trecensis.*
			Greyish chalk with *Holaster subglobosus.*
	Ammonites varians.	Greyish or whitish chalk, often with flinty concretions, *Am. varians, Am. rotomagensis.*	Grey marly chalk with *Am. varians, Am. rotomagensis* and *Rhync. mantelliana.*
		Hard glauconitic chalk with phosphatic nodules and fossils, *Am. varians, Scaph. æqualis.*	Grey chalk with *Plocoscyphia labrosa* and *Scaph. æqualis.*
		(Absent.)	Glauconitic marly sand with *Stauronema Carteri.*
		(Absent.)	(Absent.)
	Thickness- -	From 80 to 143 feet.	About 200 feet.

CENTRAL AREA (WILTSHIRE.)	HERTFORD, BEDFORD, CAMBRIDGE & SUFFOLK.	NORTHERN AREA (LINCOLNSHIRE AND YORKSHIRE).
Smooth white chalk with two layers of flints.	Massive white chalk with flints, *Hol. planus.*	Top not fixed.
Soft white chalk in thick beds with seams of marl, *Ter. lata* and *Gal. subrotundus ;* occasional flints.	Massive white chalk with many flints ; *Ter. lata*, *Gal. subrotundus* and *Inoc. Cuvieri.*	Firm white chalk with frequent layers of flint and seams of dark grey clay, *Inoc. Cuvieri.*
Solid white chalk without flints, becoming nodular and passing down into hard nodular chalk (Melbourn Rock), *Rhynch. Cuvieri* and *Inoc. mytiloides.*	Firm chalk with a few flints, becoming nodular and passing down into hard nodular chalk (Melbourn Rock), with *Rhynch. Cuvieri* and *Inoc. mytiloides.*	Hard greyish chalk in regular beds full of *Inoceramus*-shell. Not more than 15 feet and no harder bed at base. *Rh. Cuvieri* and *Inoc. mytiloides.*
From 80 to 140 feet.	About 230 feet.	? 120 to 180 feet.
Soft grey marl (thin).	Soft marl and white chalk.	Soft grey or purple marl.
White chalk with layers of hard chalk ; few fossils.	Whitish chalk with few fossils, *Hol. trecensis.*	Greyish white chalk with local bands of pink chalk, *Offaster sphæricus* and *Am. rotomagenis.*
Greyish white chalk with *Am. Austeni* and *Hol. subglobosus.*	Grey chalk with *Hol. subglobosus.*	
—	Totternhoe Stone.	Totternhoe stone.
Tough greyish chalk, often with siliceous concretions and layers of harder chalk, *Am. rotomagensis.*	Tough marly chalk passing down into soft marl with *Am. varians*, *Inoc. latus* and *Rhynch. Martini.*	Bedded grey chalk with *Rhynch. mantelliana.*
Grey marly chalk with *Am. varians* and *Inoc. latus.*		Rough grey shelly chalk with *Inoc. latus* and *Am. varians.*
Glauconitic chalk with *Stauronema Carteri.*	Cambridge nodule bed with fossils derived from the Gault and *Aucel. gryphæoides.*	Sponge bed, a pinkish limestone with *Aucellina gryphæoides.*
Glauconitic sand with *Am. varians*, *Am. Mantelli* and *Catopygus columbarius.*	(Absent.)	(Absent.)
From 230 to 250 feet.	From 180 to 160 feet.	Average, 75 to 80 feet.

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Names printed in italics are those of fossils which are figured, or to which special reference is made.

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PLATE IV.

Fig. 1.

Chalk Marl, Compton Bay, Isle of Wight (near the base.)

A shelly Chalk Marl, the shell fragments in this case are chiefly derived from Inoceramus and Terebratula.

a.a. Inoceramus prisms ; *b.* fragment of Terebratula ; *c. Globigerina cretacea* ; *d.* a grain of glauconite ; *e.* foraminiferal cell partly filled with glauconite.

Fig. 2.

Chalk Marl, Charlton Cutting, Midland Railway, about 4½ miles N.W. of Luton ; 10 ft. below the Totternhoe Stone.

This marl consists chiefly of amorphous material and small shell particles, a few larger fragments and foraminifera.

a.a. Inoceramus prisms ; *b. Globigerina cretacea* ; *c. Pulvinulina* ; *d. Anomalina ammonoides*

Plate IV.

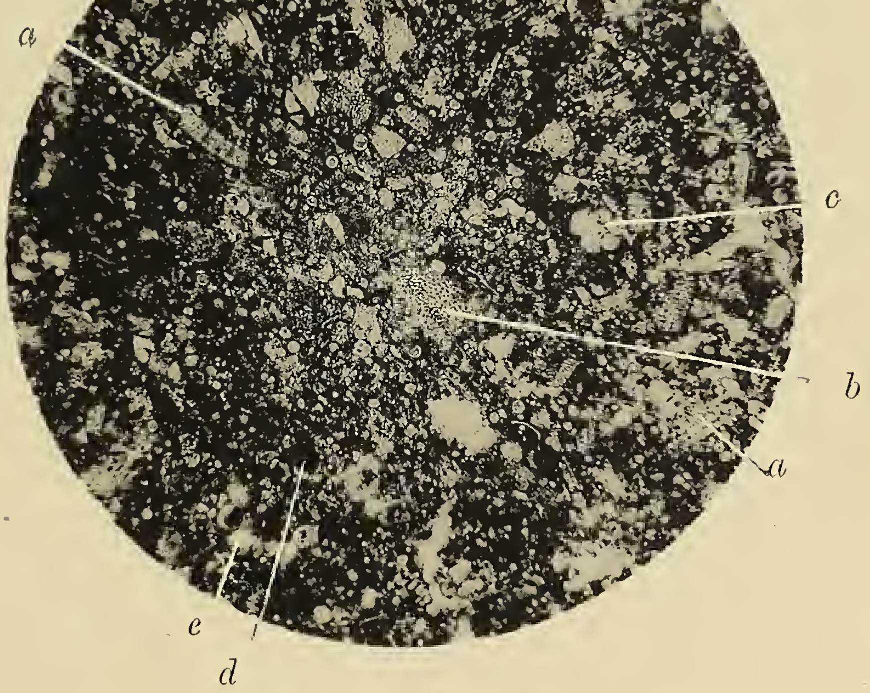


Fig. 1. Chalk Marl (base).
Compton Bay, Isle of Wight.
×22 diam.

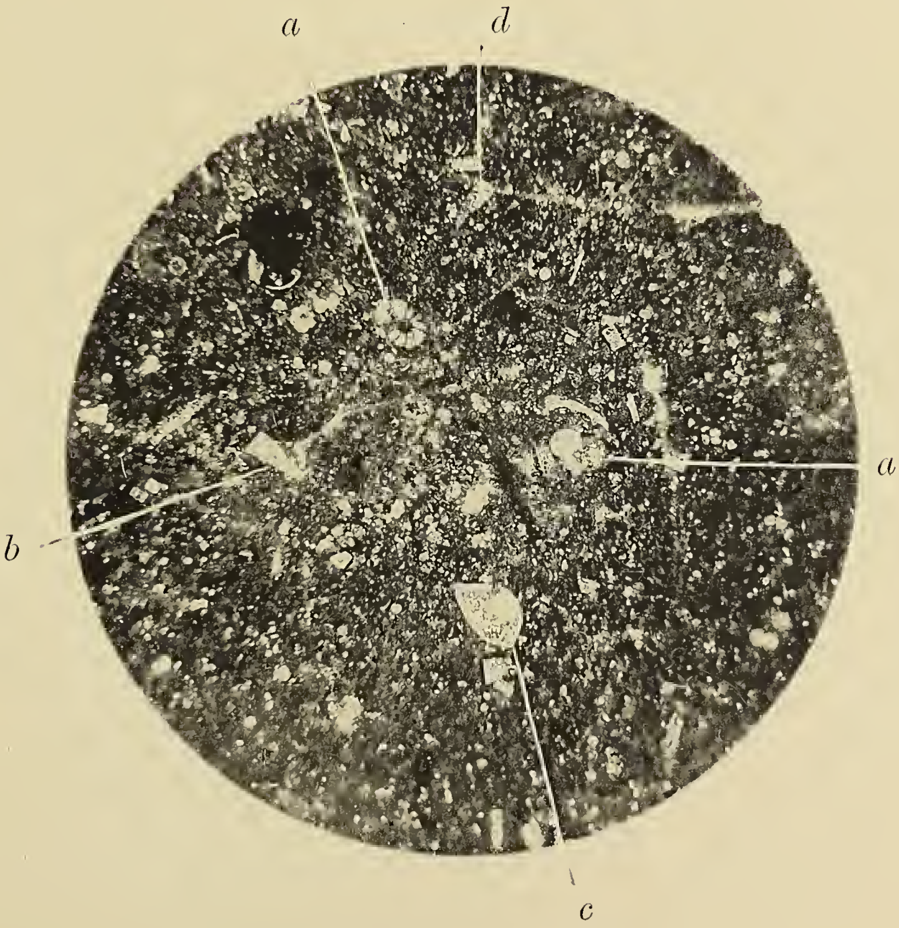


Fig. 2. Chalk Marl (upper part).
Charlton Cutting, Bedfordshire.
× 22 diam.

PLATE V.

Fig 1.

Totternhoe Stone, Totternhoe.

The lighter portions of this figure represent minute particles of shell which appear to be largely derived from Inoceramus (*a*) and a few small quartz-grains. Amongst them may here and there be noticed foraminiferal cells (*b*).

Fig. 2.

Lower Chalk, Grove Mill, Hitchin, about 35 ft. below the zone of *Actinocamax plenus.*

Chiefly amorphous calcareous material with a few shell fragments, foraminifera and "spheres."

a. nest of shell fragments, all prisms of Inoceramus; *b. Globigerina marginata*; *c.* a foraminiferal cell; *d.* "spheres."

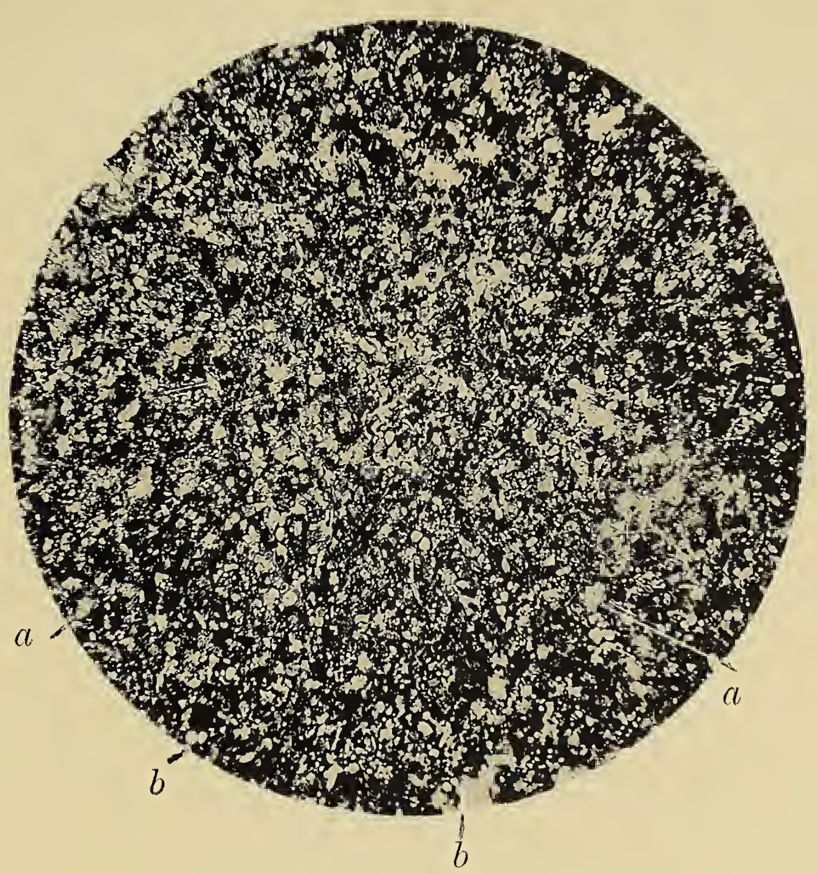


Fig. 1. Totternhoe Stone.
Totternhoe.
×22 diam.

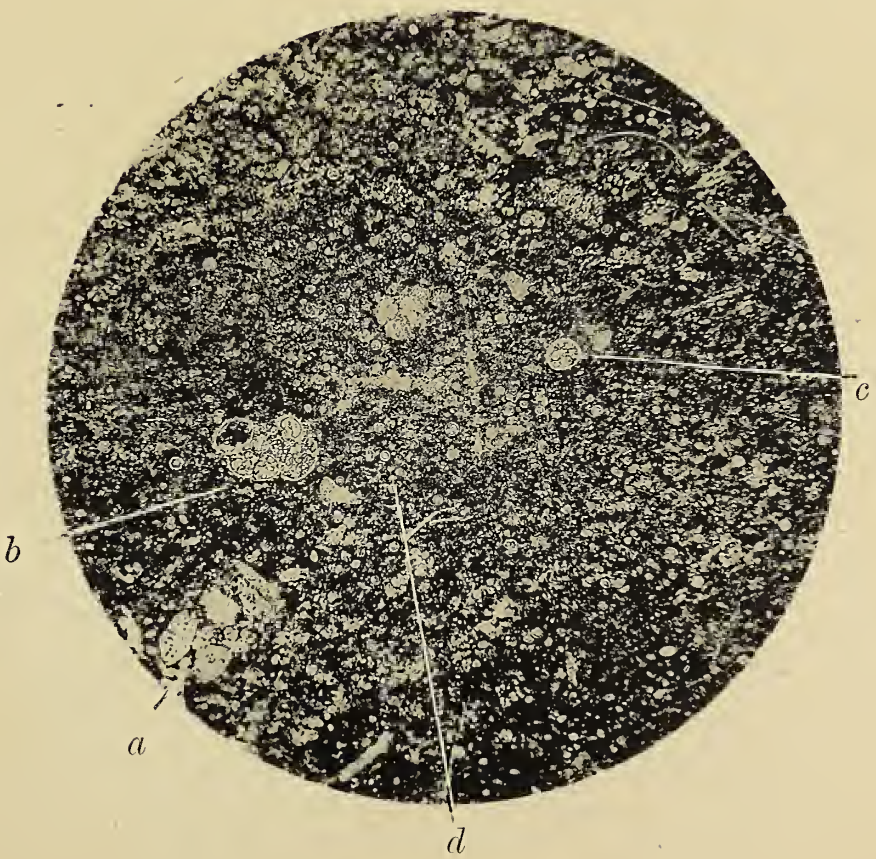


Fig. 2. Lower Chalk.
Hitchin.
× 22 diam.

PLATE VI.

FIG. 1.

MELBOURN ROCK, DOVER ("THE GRIT BED").

This is an extremely well-marked form of nodular rock, occurring not only in the "Grit Bed" but in many exposures at this horizon, as well as in the Richmond well-boring.

a.a. small nodules of chalk; *b.* matrix consisting chiefly of Inoceramus-prisms; *c.c.* coarse fragments of Inoceramus-shell showing prismatic structure; *c.* the prisms are here cut diagonally.

FIG. 2

MELBOURN ROCK, HITCHIN, HERTS.

A nodular rock in which the nodules are not so clearly defined as in Fig. 1.

a. portion of a nodule; *b.* the matrix containing a large proportion of coarse shell fragments, chiefly prisms of *Inoceramus mytiloides; c.* a small tubular boring in the nodule, now filled with granular crystalline calcite.

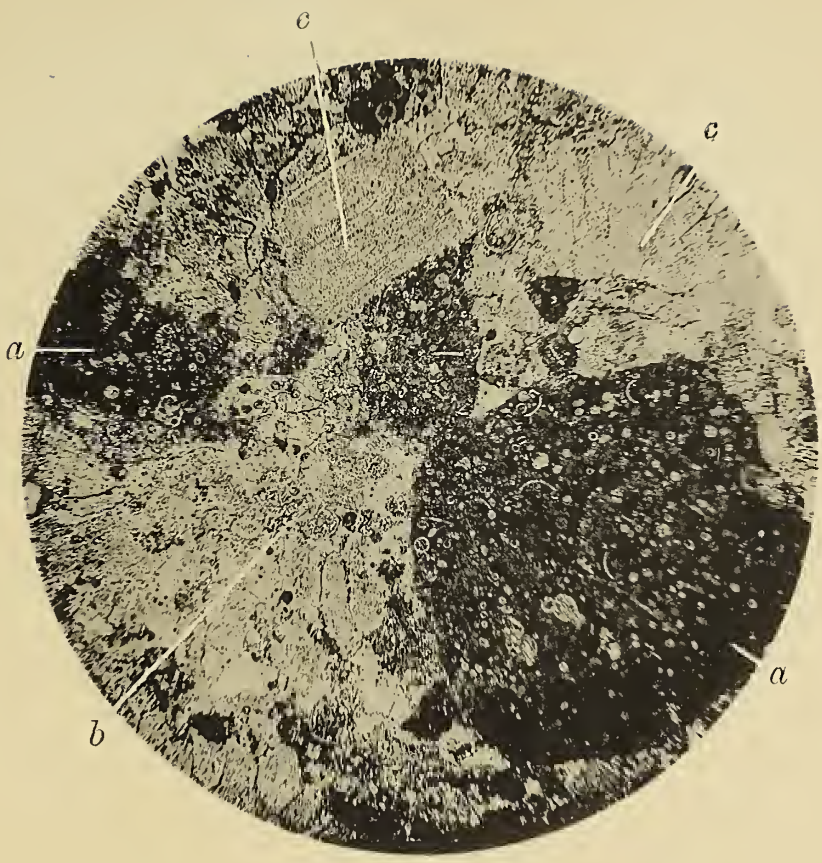


Fig. 1. Melbourn Rock (Grit Bed).
Dover.
Shewing nodule and matrix. × 22 diam.

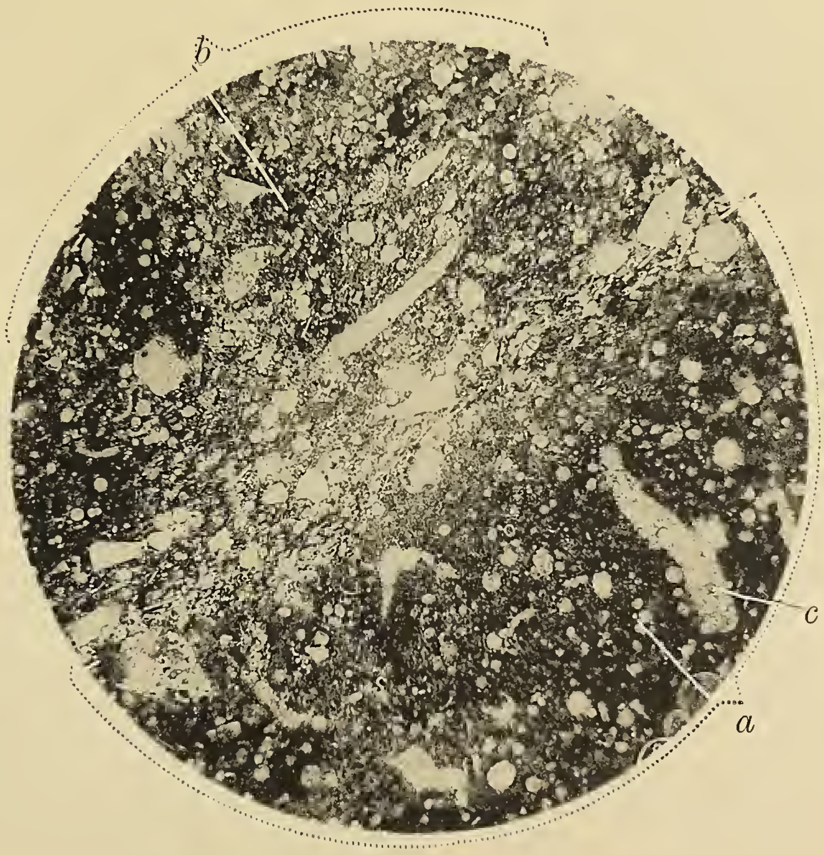


Fig. 2. Melbourn Rock.
Hitchin.
Shewing portion of nodule and matrix. × 22 diam.

PLATE VII.

Fig. 1.

Melbourn Rock, Hitchin, Herts.

The lower and whiter part. The rock at this horizon consists of extremely fine calcareous particles, presumably derived from shells, and of "spheres." Allowing for a little variation in the size and quantity of the shell fragments, as well as in the number and the definition in the outline of the "spheres," this is the type of chalk which occurs immediately above the zone of *Actinocamax plenus* over a very wide area.

Fig. 2.

Melbourn Rock, Hitchin, Herts.

The upper yellow bed. In the upper part of the Melbourn Rock the shell fragments are very abundant and usually coarse. This type of chalk does not extend over so wide an area, and is confined to the Midland, Southern and South Eastern Counties. *a. a a. a.* coarse shell-fragments, nearly all derived from *Inoceramus mytiloides*, rarely an Echinoderm spine, plate, or ossicle occurs; a few Foraminifera; *b. Gaudryina; c. Globigerina.*

Plate VII.

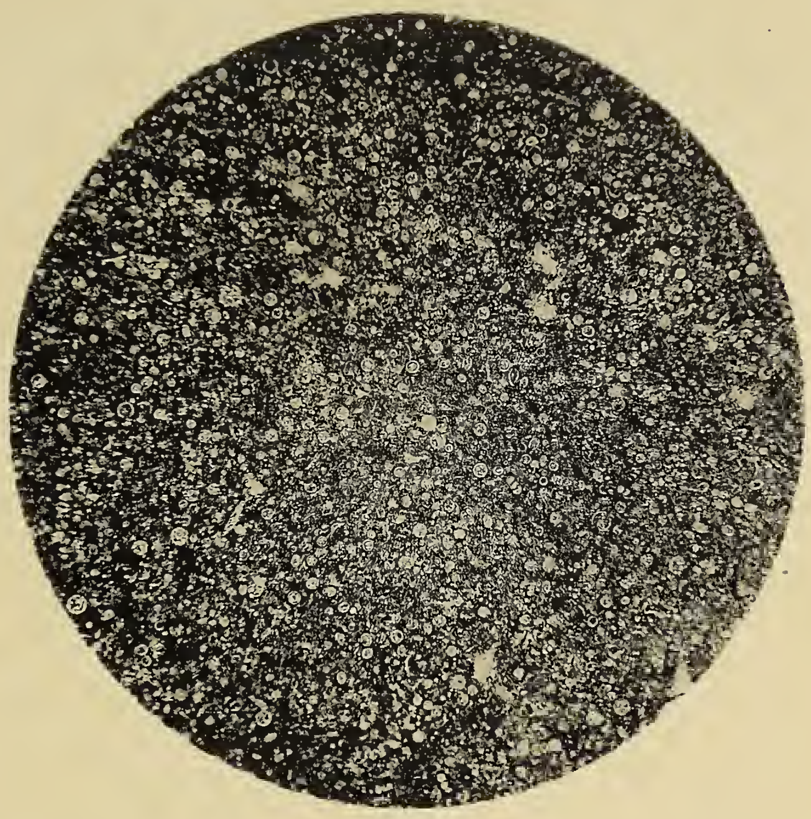


Fig. 1. Matrix of lower and whiter portion of Melbourn Rock.
Hitchin.
×22 diam.

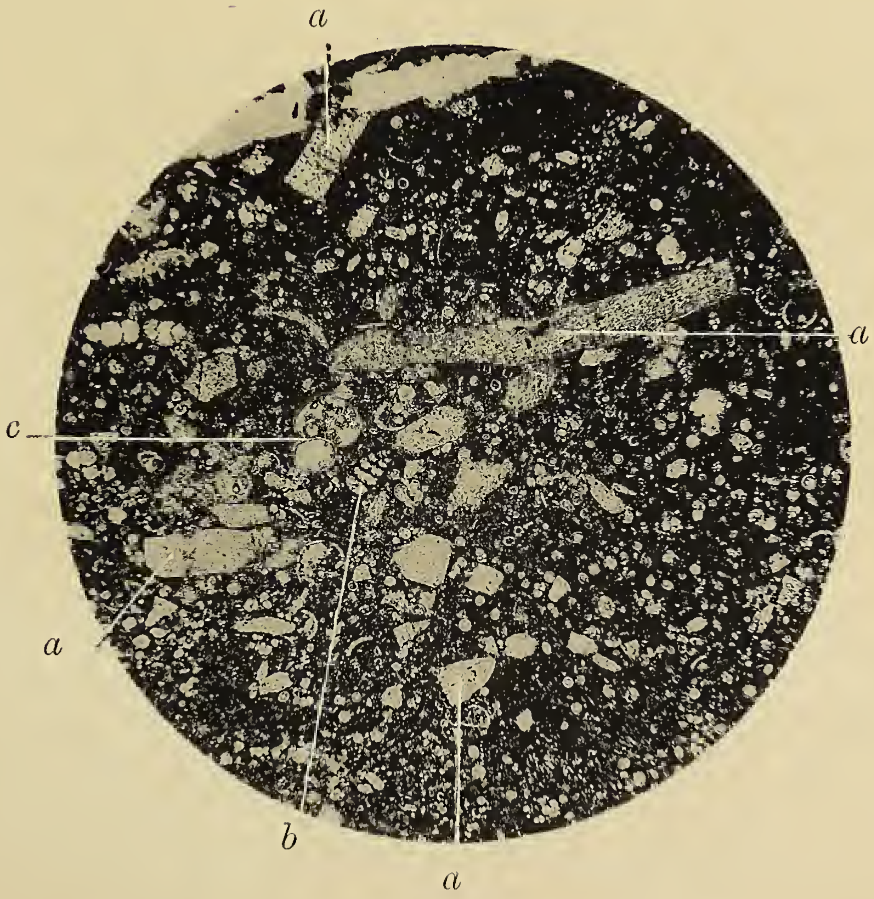


Fig. 2. Matrix of upper and yellower portion of Melbourn Rock.
Hitchin.
×22 diam.

PLATE VIII.

Fig. 1.

Base of the Terebratulina zone, Hitchin, Herts.

This figure shows a structure very characteristic of the chalk in the upper part of the zone of *Rhynchonella Cuvieri*, and the base of the *Terebratulina* zone.

"Spheres" are very numerous. These usually show a cell wall with the interior filled with granular calcite, *a. a.;* or the wall may be obliterated, *b;* *c. Globigerina cretacea;* *d. Globigerina marginata.*

Fig. 2.

Upper Chalk zone of Belemnitella quadrata, Salisbury, Wilts.

A soft chalk consisting chiefly of amorphous material with a few shell fragments and minute foraminifera, chiefly Globigerinæ and Textularians. Amongst the latter are many *T. globulosa*, a characteristic form in many sections of Upper Chalk.

a.a.a.a. Textularia globulosa; b. Globigerina æquilateralis; c. Foraminiferal cell.

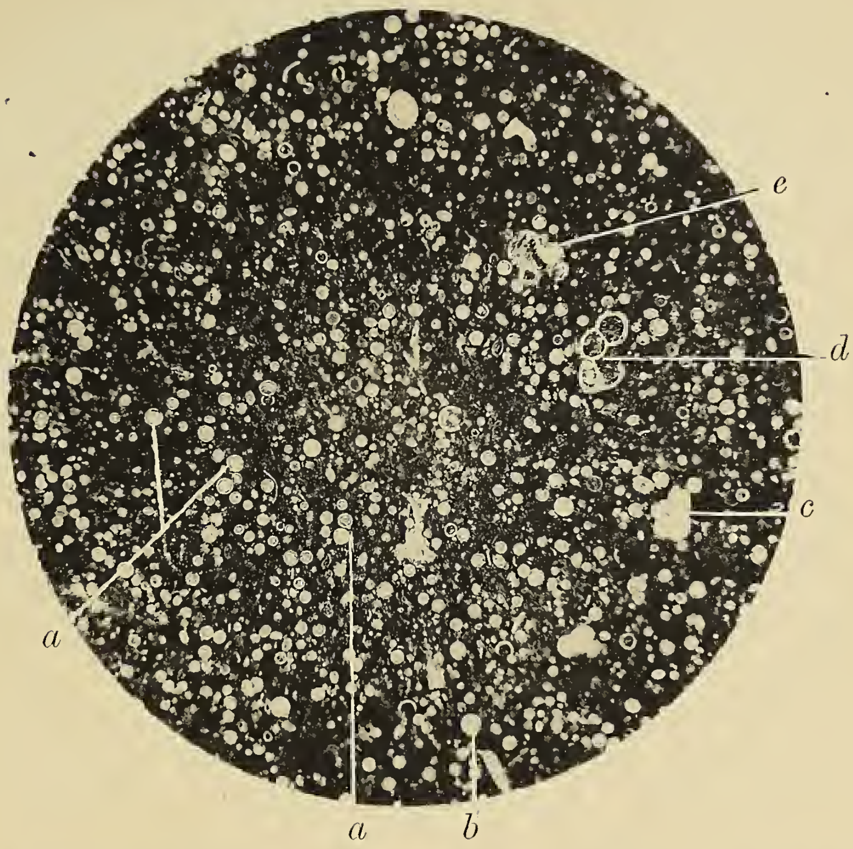


Fig. 1. Middle Chalk. Base of Zone of Terebratulina gracilis.
Hitchin.
×22 diam.

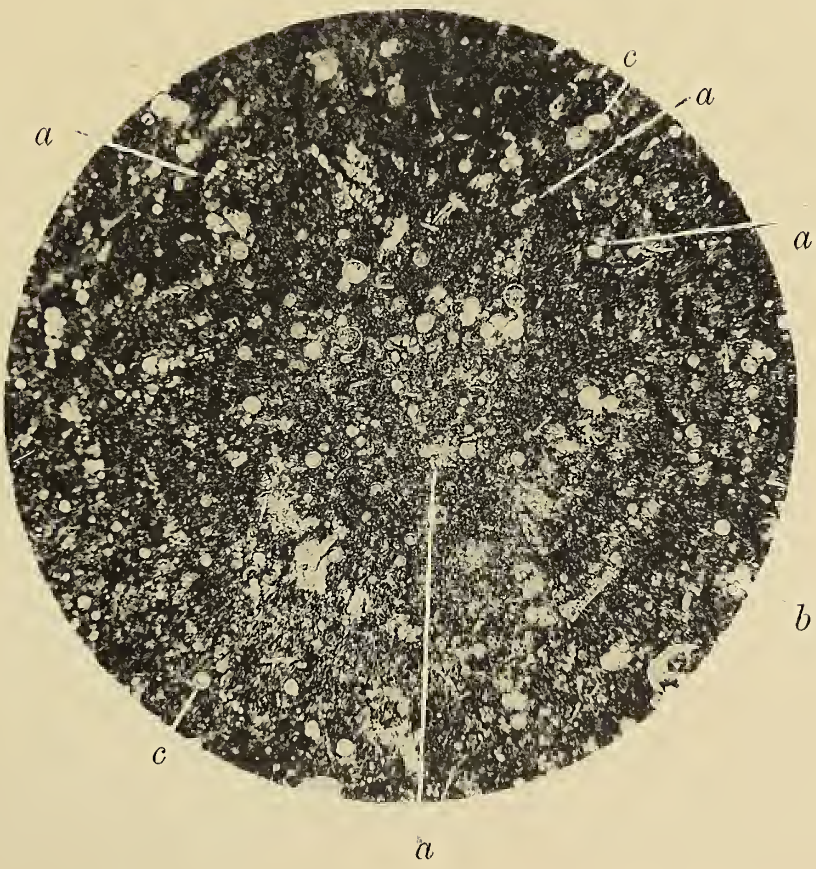
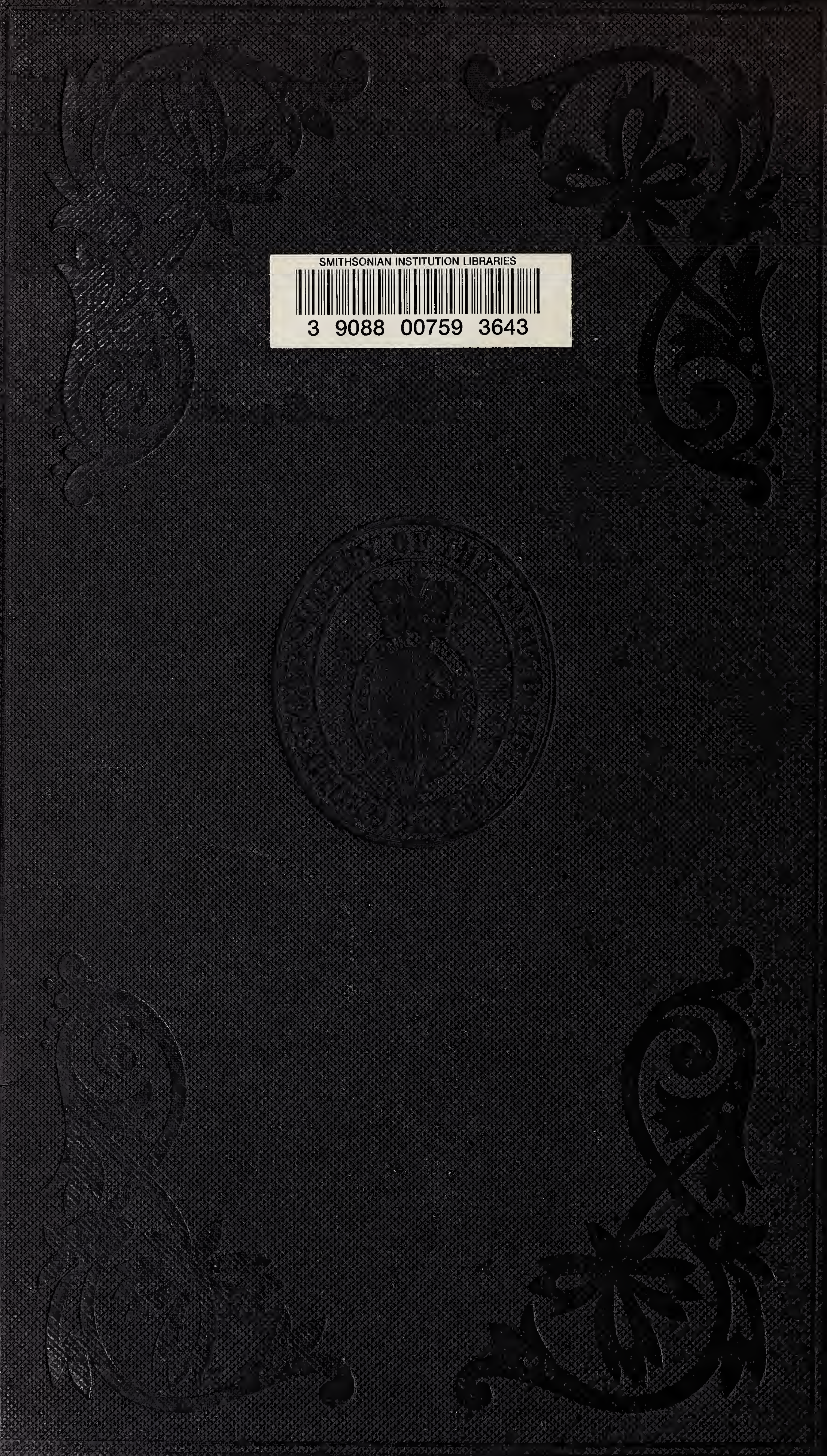


Fig. 2. Upper Chalk. Zone of Belemnitella quadrata.
Salisbury.
×22 diam.



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